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BOEING-WICHITA MATERIALS & RESEARCH DEVELOPMENT PROGRAMS 1957-1961

SUMMARY REPORT NO. 2

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BY

THE BOEING COMPANY
WICHITA DIVISION

PREPARED BY

A. H. POE AND H. E. SHIGLEY

AIR FORCE CONTRACT AF33(616)-8141
PROJECT NO. 1(8-7381)
TASK NO. 73812

PREPARED FOR

INFORMATION PROCESSING SECTION
APPLICATION LABORATORY
DIRECTORATE OF MATERIALS & PROCESSES
AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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CODIFICATION OF MATERIALS R&D

Class of Material	Nature of R&D	Primary Objective of R&D
1. Iron and Steel	1. Extraction, Synthesis and Purification	1. Structural and Mechanical
2. Light Metals and Alloys	2. Alloying, Compounding & Effects of Variations	2. Electrical and Magnetic
3. Heavy Non-Ferrous Metals & Alloys	3. Methods of Processing	3. Optical & Acoustical (incl. Transducer)
4. Inorganic Non-Metallic Solids	4. Surface Treatment and Coating	4. Chemical
5. Elastomers	5. Methods of Analysis Test & Inspection	5. Protection against Ballistic & Other Hazards
6. Plastics (including Reinforced Plastics)	6. Joining (Adhesive Bonding, Brazing, Soldering, Welding)	6. High Temperature
7. Liquid & Semi-Solid High Polymers	7. Mechanical & Physical Properties	7. Low Temperature
8. Fibrous and Filamentary Materials	8. Effects of Chemical & Physical Environments	8. Radiological and Nuclear
9. Composite Materials	9. Research and Theory Development	9. Deterioration Prevention (including Packaging)
0. Miscellaneous and General	0. Miscellaneous	0. Miscellaneous

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    7-6-1 Adhesive, Shell Epon 928

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BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals

CODE: 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

III. GENERAL DESCRIPTION:

The objective of this program was to determine the longitudinal and transverse tensile properties of three different gages of AM 350 at room temperature, 600°F, 800°F and 1000°F., after prior exposure at these temperatures under zero stress conditions.

IV. DEVELOPMENTAL BACKGROUND:

In conjunction with advanced design studies on supersonic aircraft, a literature survey was made to determine the optimum material for wing skins operating between 600°F and 800°F. Principle requirements were: oxidation and corrosion resistance, strength and stability at temperature, and fabricability. AM 350 seemed to be the most likely candidate, and this study was conducted to provide reliable design data on this alloy.

AUTHOR: G. Wadsworth

DATE: 9-12-61

I. **CATEGORY:** Metals CODE: 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

1. Tensile - Given in Tables I - XX and Figures 1 - 8. All values are for condition SCT.

2. Thermal Stability - Given in Tables I - II and Figures 1 - 8.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Metals **CODE:** 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (continued)

A. Mechanical (continued)

TABLE I. TENSILE PROPERTIES OF .125 GAGE AM350 AFTER NO [illegible] EXPOSURE

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse sample

Spec. No.*	Test Temp. F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Hardness Before Exposure	Rc Hardness After Exposure
1L	RT	192.6	172.0	16.0	44.0	No Exposure
2L		191.7	172.8	16.5	44.1	
3L		192.1	177.4	17.5	44.4	
AVG.		192.1	173.1	16.7	44.2	
1T		199.0	162.5	15.0	43.8	
2T		197.0	160.1	16.0	43.6	
3T		192.9	162.8	15.0	44.6	
AVG.		197.0	162.1	15.3	44.0	
4L	600°F.	172.4	130.9	10.0	43.1	
5L		172.6	132.9	10.0	44.0	
6L		172.4	126.4	10.5	44.3	
AVG.		171.8	129.4	10.2	43.8	
4T		171.7	132.2	8.0	42.1	
5T		175.0	128.8	8.5	43.1	
6T		169.7	133.0	10.5	44.1	
AVG.		172.1	134.3	9.0	43.1	
7L	800°F	169.9	124.4	11.0	43.2	
8L		168.6	123.0	10.0	44.2	
9L		167.2	118.6	10.0	43.0	
AVG.		168.6	122.0	10.3	43.5	
7T		162.4	117.2	9.5	42.1	
8T		163.2	121.8	9.5	43.8	
9T		161.1	113.0	10.0	43.5	
AVG.		162.2	117.3	9.7	43.1	
10L	1000°F	138.5	112.0	10.5	42.3	
11L		136.3	111.8	10.5	42.5	
12L		132.4	98.4	8.5	44.0	
AVG.		135.7	107.4	9.8	42.9	
10T		134.6	99.5	8.5	42.9	
11T		127.9	96.3	10.0	43.0	
12T		137.7	111.9	10.0	42.0	
AVG.		133.4	102.6	9.5	42.3	

Page 3

TABLE I

AUTHOR: G. Wadsworth GW **DATE:** 9-12-61 **PAGE** 3.

I. CATEGORY: Metals **CODE:** 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE II. TENSILE PROPERTIES OF .125 GAGE AM350 AFTER PRIOR EXPOSURE OF 10 HR AT 600°F.

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
13[illegible]	RT	156.3	164.6	12.0	41.6	43.2
14[illegible]		149.0	159.8	12.5	42.7	43.8
15[illegible]		150.4	159.6	14.0	43.5	42.8
AVG.		152.2	162.0	12.8	42.6	43.2
16[illegible]	600°F.	164.3	123.2	9.5	42.8	43.5
17[illegible]		164.9	122.6	10.5	42.9	43.5
18[illegible]		163.2	124.4	10.5	43.0	43.0
AVG.		164.0	125.4	10.2	42.9	43.3
19[illegible]	800°F.	167.7	112.3	10.5	42.7	43.2
20[illegible]		165.1	111.9	11.0	43.6	43.1
21[illegible]		165.6	112.8	11.5	44.0	42.1
AVG.		166.1	113.7	11.0	43.4	42.8
22[illegible]	1000°F	[illegible]	129.1	7.0	43.4	43.0
23[illegible]		[illegible]	[illegible]	9.0	43.4	42.9
24[illegible]		[illegible]	93.8	9.0	43.2	43.5
AVG.		131.9	115.7	8.7	43.3	43.1

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE II

I. **CATEGORY:** Metals **CODE:** 1-C-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE III. TENSILE PROPERTIES OF .125 GAGE AM350 AFTER PRIOR EXPOSURE OF 50 HR at 600°F.

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
49T	RT	191.7	162.9	14.0	43.7	43.2
50T		188.9	161.6	14.5	43.0	43.8
51T		188.8	161.3	13.5	44.0	43.6
AVG.		189.8	161.9	14.0	43.6	43.7
52T	600°F.	169.0	129.4	10.0	42.8	43.5
53T		172.8	129.2	8.5	43.3	43.0
54T		177.1	135.3	10.0	43.1	43.0
AVG.		173.0	131.3	9.5	43.0	43.2
55T	800°F.	165.9	114.5	10.0	44.0	43.1
56T		[illegible]	118.0	9.5	43.8	43.1
57T		165.9	127.4	9.5	43.7	43.3
AVG.		167.0	120.0	9.7	43.8	43.2
58T	1000°F.	139.7	117.1	10.0	42.4	44.0
59T		132.2	94.4	8.5	[illegible]	43.1
60T		143.8	118.5	9.5	42.6	42.8
AVG.		138.2	110.0	9.3	42.8	43.3

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE III

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE V.

TENSILE PROPERTIES OF .125 GAGE AM350 AFTER [illegible] HOUR EXPOSURE AT [illegible] °F.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Hardness Before Exposure	Rc Hardness After Exposure
25T	RT	190.6	169.4	17.5	43.6	42.1
26T		191.2	166.0	17.5	42.9	43.1
27T		193.5	168.0	17.5	43.6	43.9
Avg.		192.8	167.8	17.5	43.4	43.0
28T	600°F.	170.7	131.1	11.5	43.0	44.2
29T		171.4	131.6	9.5	43.8	44.0
30T		169.4	134.9	9.0	43.6	43.5
Avg.		170.5	132.5	10.0	43.4	43.9
31T	800°F.	171.2	125.6	8.0	42.9	43.7
32T		167.2	117.5	9.5	43.0	44.1
33T		165.6	119.2	9.5	44.3	44.1
Avg.		168.0	120.8	9.0	43.4	44.0
34T	1000°F.	122.3	89.2	9.0	43.0	44.3
35T		[illegible]	97.9	9.5	43.6	44.1
36T		[illegible]	98.2	9.0	43.8	44.2
Avg.		[illegible]	95.3	[illegible]	43.4	44.2

TABLE V

AUTHOR: G. Wadsworth *GW* DATE: 9-12-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE VI.

TENSILE PROPERTIES OF .125 GAGE AM350 AFTER [illegible] EXPOSURE
OF 50 KSI. AT 800°F.

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Before Exposure	Rc After Exposure
61T	RT	196.9	170.0	17.0	42.6	44.6
62T		196.9	168.2	17.0	43.2	45.0
63T		198.6	171.2	17.0	43.5	44.0
AVG.		197.5	170.0	17.0	43.1	44.5
64T	600°F.	168.8		9.5	43.5	44.5
65T		165.8	132.9	9.5	43.2	44.3
66T		167.4	137.7	8.5	43.7	44.5
AVG.		167.3	135.3	9.2	43.4	44.4
67T	800°F.	163.2	123.0	9.5	42.5	44.6
68T		163.4	126.4	9.0	43.3	44.3
69T		164.0	124.4	9.5	44.2	44.5
AVG.		163.5	124.6	9.3	43.3	44.4
70T	1000°F	132.4	96.0	9.5	42.1	44.2
71T		132.3	103.7	8.5	43.1	44.8
72T		129.7	97.5	7.5	43.9	44.4
AVG.		136.4	99.2	8.5	43.0	44.4

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE VI

AUTHOR: G. Wadsworth DATE: 9-12-61

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I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE VII. [illegible]

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Readings Before Exposure	RC Readings After Exposure
[illegible]	RT	199.4	174.4	16.5	43.2	44.9
[illegible]		198.2	172.1	16.5	43.1	45.2
[illegible]		198.8	172.0	16.5	43.6	45.0
AVG.		198.8	172.8	16.5	43.3	45.2
[illegible]	600°F.	167.4	136.7	8.0	43.1	45.2
[illegible]		157.4	129.6	7.5	43.6	45.0
[illegible]		162.0	134.0	9.0	42.3	45.0
AVG.		167.6	133.4	8.2	43.0	45.0
[illegible]	800°F.	163.2	136.0	7.5	42.2	44.5
[illegible]		161.3	130.6	7.5	43.0	43.5
[illegible]		162.2	127.4	8.0	42.8	43.7
AVG.		162.2	[illegible]	7.7	43.0	43.9
[illegible]	1000°F.	128.7	94.8	7.5	43.1	44.2
[illegible]		128.9	89.9	8.5	43.2	45.4
[illegible]		129.2	95.7	9.5	43.6	43.6
AVG.		[illegible]	[illegible]	8.5	43.3	44.4

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE VII

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals   **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE VIII. [illegible]

OF 10 HRS. AT 1000°F.

[illegible]	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	[illegible] Before Exposure	[illegible] After Exposure
[illegible]	RT	170.2	141.0	13.5	42.9	36.4
[illegible]		168.5	132.5	13.0	43.1	37.1
[illegible]		170.1	136.8	14.5	43.4	35.9
AVG.		169.6	141.1	13.7	43.1	36.5
[illegible]	600°F.	138.1	118.8	9.0	42.8	36.8
[illegible]		139.2	122.1	9.0	43.1	36.6
[illegible]		138.1	120.0	8.5	42.9	36.4
AVG.		138.4	120.3	8.8	42.6	36.3
[illegible]	800°F.	130.0	107.1	[illegible]	43.0	36.9
[illegible]		130.0	127.6	9.0	43.1	37.2
[illegible]		130.9	129.4	9.0	42.9	36.0
AVG.		130.3	108.0	9.0	43.0	36.7
[illegible]	1000°F.	107.8	87.6	10.5	42.8	37.1
[illegible]		107.9	87.0	11.5	43.1	36.8
[illegible]		107.8	86.5	11.0	42.9	36.6
AVG.		107.8	87.0	11.0	42.9	36.8

* [illegible]

TABLE VIII

AUTHOR: G. Wadsworth   **DATE:** 9-12-61

I. CATEGORY: Metals CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE IV.

TENSILE PROPERTIES OF .125 GAGE SHEET AFTER [illegible] EXPOSURE OF 50 HR. AT 1000°F.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Hardness Before Exposure	Rc Hardness After Exposure
[illegible]	RT	132.2	128.6	13.5	43.1	36.2
[illegible]		131.5	129.0	13.0	42.9	35.8
[illegible]		121.6	129.0	13.0	43.0	36.0
AVG.		131.4	128.9	13.1	43.0	36.0
[illegible]	600°F.	141.2	116.0	8.5	42.8	35.6
[illegible]		140.8	116.5	8.5	43.1	36.4
[illegible]		*141.7	118.6	7.0	43.2	35.9
AVG.		141.2	117.0	8.0	43.0	36.0
[illegible]	800°F.	133.6	102.8	9.0	42.6	35.9
[illegible]		132.6	106.5	8.0	42.2	36.3
[illegible]		132.6	103.7	8.5	41.9	36.5
AVG.		132.9	104.3	8.5	42.2	36.2
[illegible]	1000°F.	114.4	95.7	11.0	43.5	36.2
[illegible]		112.2	85.2	13.5	43.1	36.0
[illegible]		108.9	83.5	11.0	42.7	37.0
AVG.		111.2	88.1	11.8	43.1	36.4

TABLE IV

BOEING AIRPLANE COMPANY
WICHITA DIVISION

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE X. TENSILE PROPERTIES OF .125 GAGE AM350 AFTER [illegible] EXPOSURE
OF 100 HRS AT 1000°F

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
109T	RT	172.5	123.2	13.0	42.4	36.1
110T		172.8	143.4	12.5	42.6	35.8
111T		170.9	129.6	13.5	43.9	36.1
AVG.		171.4	132.1	13.0	43.0	36.0
112T	600°F.	141.7	115.5	8.0	43.0	36.2
113T		141.7	114.8	8.5	44.2	35.6
114T		138.8	115.9	8.5	43.0	36.0
AVG.		140.7	115.4	8.3	43.4	35.9
115T	800°F.	135.1	103.6	8.0	42.6	36.1
116T		125.6	103.6	8.5	42.1	36.0
117T		132.6	103.8	8.5	43.9	35.5
AVG.		132.4	103.6	8.3	42.8	35.8
118T	1000°F	102.4	82.4	10.5	43.5	35.3
119T		107.7	82.8	10.5	42.7	35.4
120T		102.7	82.8	12.0	43.6	35.4
AVG.		106.3	82.3	11.0	43.3	35.4

TABLE X

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XI. TENSILE PROPERTIES OF .032 GAGE AM350 AFTER 10 HOUR EXPOSURE

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
1L	RT	198.2	164.4	11.5	42.1	No Exposure
2L		199.4	170.6	12.0	41.9	
3L		195.0	164.6	14.0	42.3	
AVG.		197.5	166.5	12.5	42.1	
1T		196.2	159.4	13.0	41.3	
2T		196.3	173.3	12.0	41.2	
3T		[illegible]	166.8	12.0	41.3	
AVG.		193.8	165.8	12.3	41.3	
4L	600°F.	172.1	131.8	5.0	41.7	
5L		182.9	138.2	5.5	41.9	
6L		173.7	132.5	5.5	41.9	
AVG.		176.2	134.2	5.3	41.8	
4T		165.0	128.2	5.5	41.8	
5T		167.5	131.3	6.5	41.8	
6T		167.6	133.3	5.5	41.8	
AVG.		166.7	130.9	5.8	41.8	
7L	800°F.	162.7	98.2	8.0	42.2	
8L		165.5	107.8	7.5	42.0	
9L		177.8	129.4	7.0	42.0	
AVG.		168.7	109.1	7.5	42.1	
7T		170.1	111.5	7.5	42.2	
8T		143.4	133.2	6.0	41.1	
9T		168.2	122.7	5.5	40.5	
AVG.		160.6	114.8	6.3	40.6	
10L	1000°F.	139.3	80.6	7.5	40.3	
11L		141.8	105.9	6.0	41.3	
12L		113.1	105.3	6.5	41.9	
AVG.		131.4	97.3	6.7	41.2	
10T		127.8	97.7	4.0	40.9	
11T		129.4	99.1	5.5	40.7	
12T		131.9	96.1	6.0	40.4	
AVG.		129.6	97.6	5.2	40.7	

Page 13

TABLE XI

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE XII. [illegible] [illegible] OF .0[illegible] GAGE [illegible] AFTER [illegible] EXPOSURE OF 10 HRS. AT 600°F.

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Before Exposure	RC After Exposure
13[illegible]	RT	197.0	173.2	13.0	41.5	41.8
14[illegible]		198.8	175.8	11.5	41.1	[illegible]
15[illegible]		196.4	172.1	13.5	41.3	[illegible]
AVG.		197.4	173.7	12.7	41.3	41.4
16[illegible]	600°F.	172.6	130.3	3.5	41.8	41.0
17[illegible]		172.6	137.2	5.0	41.5	40.6
18[illegible]		167.5	122.3	7.0	41.7	41.7
AVG.		169.9	129.9	5.8	41.0	41.1
19[illegible]	800°F.	167.9	122.3	5.5	41.5	[illegible].6
20[illegible]		162.3	127.7	4.5	41.0	41.4
21[illegible]		171.8	117.6	5.0	41.4	41.5
AVG.		169.3	121.9	5.0	41.3	41.5
22[illegible]	1000°F	136.5	85.9	[illegible].5	41.0	41.4
23[illegible]		114.1	87.4	6.0	41.2	41.8
24[illegible]		137.0	105.9	5.0	41.1	41.3
AVG.		129.2	93.1	5.2	41.1	41.2

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XII

I. CATEGORY: Metals **CODE:** 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE [illegible]

TENSILE PROPERTIES OF [illegible] AFTER [illegible] HOUR EXPOSURE
[illegible]

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
[illegible]	RT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		197.0	172.1	12.5	[illegible]	[illegible]
[illegible]		196.1	165.7	[illegible]	[illegible]	[illegible]
[illegible]		198.1	172.2	11.5	[illegible]	[illegible]
[illegible]	600°F.	172.2	136.4	6.5	40.5	[illegible]
[illegible]		173.2	135.1	6.5	40.5	41.9
[illegible]		173.6	134.7	7.0	[illegible]	41.8
[illegible]		173.0	135.4	6.6	[illegible]	41.6
[illegible]	800°F	167.5	121.5	7.5	41.1	41.3
[illegible]		172.1	[illegible]	5.5	[illegible]	41.6
[illegible]		173.5	123.1	[illegible]	41.4	41.4
[illegible]		[illegible]	[illegible]	6.3	41.2	41.4
[illegible]	1000°F	123.0	84.8	9.5	41.6	41.8
[illegible]		[illegible]	90.3	[illegible]	41.4	41.5
[illegible]		112.2	87.2	7.5	41.4	41.5
[illegible]		127.9	87.4	8.3	41.1	41.6

TABLE XIII

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE XIV.

TENSILE PROPERTIES OF AM 350 CRES SHEET AFTER EXPOSURE OF 100 HRS. AT 600°F.

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Hardness Before Exposure	Rc Hardness After Exposure
[illegible]	RT	222.6	176.1	12.5	41.8	41.1
[illegible]		239.4	172.5	12.0	41.7	41.6
[illegible]		225.6	178.4	11.5	41.5	41.3
Avg.		221.9	175.0	12.0	41.7	41.3
[illegible]	600°F.	168.6	126.6	7.0	42.1	41.5
[illegible]		172.8	135.8	6.0	41.3	41.5
[illegible]		172.8	131.1	6.0	42.1	42.1
Avg.		171.4	131.2	6.3	41.8	41.7
[illegible]	800°F.	172.2	125.7	6.5	41.2	41.2
[illegible]		174.6	126.0	5.5	42.2	42.0
[illegible]		172.9	132.2	5.0	41.8	41.0
Avg.		173.2	128.0	5.7	41.7	41.4
[illegible]	1000°F	121.5	80.2	10.5	41.2	41.1
[illegible]		125.1	88.5	6.0	41.5	41.5
[illegible]		122.0	96.4	[illegible]	41.3	41.1
Avg.		[illegible]	[illegible]	6.2	41.3	41.2

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XIV

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE [illegible] [illegible]

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	Rc Hardness Before Exposure	Rc Hardness After Exposure
25T	RT	197.2	175.5	9.5	41.5	43.[illegible]
26T		197.3	173.8	10.0	41.1	43.0
27L		196.7	172.7	11.5	41.4	42.0
28L		197.1	170.0	10.5	41.3	42.6
28T	600°F.	172.0	136.6	4.5	42.0	42.5
29T		174.4	133.0	7.0	41.2	43.0
30T		171.0	134.9	6.5	41.2	43.0
31L		172.5	134.8	6.0	41.7	42.8
31T	800°F.	173.3	130.9	4.5	41.5	43.0
32T		169.0	127.7	4.0	41.4	45.5
33T		166.2	125.8	4.5	41.4	45.0
34L		169.5	124.1	4.3	41.4	42.5
34T	1000°F.	95.4	80.2	10.0	41.5	45.5
35T		92.2	[illegible]	11.5	41.6	[illegible]
36T		106.1	[illegible]	2.0	41.4	[illegible]
[illegible]		[illegible]	[illegible]	9.6	41.5	[illegible]

TABLE XV

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE XVI

TENSILE PROPERTIES OF .032 [illegible]

[illegible]

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
[illegible]	RT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	179.5	12.5	41.9	43.3
[illegible]		[illegible]	[illegible]	[illegible]	41.8	43.1
[illegible]		[illegible]	175.5	12.5	41.9	43.1
[illegible]	600°F.	[illegible]	[illegible]	[illegible]	41.5	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	5.5	41.8	42.7
[illegible]		[illegible]	[illegible]	6.2	41.8	42.9
[illegible]	800°F.	[illegible]	[illegible]	[illegible]	42.1	42.8
[illegible]		[illegible]	[illegible]	5.0	41.5	42.8
[illegible]		[illegible]	[illegible]	[illegible]	42.1	42.5
[illegible]		177.2	[illegible]	5.3	42.9	42.7
[illegible]	1000°F.	[illegible]	89.7	[illegible]	41.1	42.8
[illegible]		[illegible]	98.2	[illegible]	41.1	42.8
[illegible]		[illegible]	100.6	5.0	42.8	43.1
[illegible]		[illegible]	96.2	5.3	42.3	42.9

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XVI

AUTHOR: G. Wadsworth GW DATE: 9-12-61

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE [illegible] TENSILE PROPERTIES OF [illegible] GAGE AM350 AFTER [illegible] EXPOSURE

[illegible]

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
97[illegible]	[illegible]	[illegible]	176.9	11.5	43.1	[illegible]
[illegible]		[illegible]	176.3	11.5	43.3	43.5
[illegible]		[illegible].9	177.1	13.5	[illegible]	43.5
[illegible]		[illegible].7	176.8	12.2	43.3	43.7
[illegible]	6[illegible]°F.	[illegible]	[illegible]	3.5	42.1	43.5
[illegible]		[illegible]	[illegible]	3.5	43.7	[illegible]
[illegible]		17[illegible].6	[illegible]	[illegible].5	[illegible].5	[illegible]
[illegible]		175.2	13[illegible].2	3.8	43.8	43.8
[illegible]	[illegible]°F.	17[illegible].1	[illegible]	[illegible]	43.2	43.5
[illegible]		17[illegible].6	[illegible]	[illegible]	[illegible]	43.0
[illegible]		[illegible]	12[illegible].5	[illegible]	[illegible].6	43.5
[illegible]		[illegible]	126.8	[illegible].3	[illegible]	43.3
[illegible]	[illegible]°F.	1[illegible].9	[illegible]	[illegible]	[illegible].6	[illegible].5
[illegible]		[illegible].3	[illegible]	5.5	[illegible]	43.5
[illegible]		[illegible].5	[illegible]	[illegible].5	43.2	43.3
[illegible]		[illegible].5	[illegible]	5.3	[illegible]	43.8

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XVII

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE [illegible] [illegible]

[illegible] [illegible] EXPOSURE

[illegible]

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
37[illegible]	[illegible]	[illegible]	150.0	11.0	42.2	34.8
[illegible]		174.2	149.7	11.5	41.5	34.6
39[illegible]		173.1	149.7	11.5	41.4	35.0
[illegible]		173.9	149.8	11.3	41.3	34.8
[illegible]	600°F.	145.7	126.7	6.0	41.0	34.2
[illegible]		140.4	122.7	[illegible].5	41.0	34.5
[illegible]		142.7	122.6	4.5	41.2	34.2
[illegible]		142.9	122.7	5.3	41.0	34.5
[illegible]	800°F.	132.2	112.1	5.0	41.5	34.4
[illegible]		137.2	111.0	5.5	40.6	35.1
[illegible]		137.0	114.5	4.0	41.0	34.9
[illegible]		137.5	112.5	[illegible]	41.0	34.8
[illegible]	1000°F.	82.0	62.4	12.0	41.1	34.4
[illegible]		123.6	83.9	10.0	41.2	34.0
[illegible]		125.5	83.6	8.5	41.2	34.6
[illegible]		97.0	76.3	[illegible]	41.2	34.3

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XVIII

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

TABLE XIX TENSILE PROPERTIES OF [illegible] AM350 AFTER [illegible]

[illegible]

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
73T	RT	176.2	139.0	12.0	41.2	34.4
74T		177.6	140.3	12.0	41.9	34.5
75T		176.4	139.1	12.5	41.1	34.4
Avg.		176.7	139.5	12.2	41.4	34.4
76T	600°F.	147.3	121.6	4.5	41.1	34.6
77T		144.3	118.2	5.0	41.4	34.3
78T		147.0	115.8	5.0	41.3	34.6
Avg.		146.2	115.5	4.8	41.3	34.5
79T	800°F.	142.7	[illegible]	4.5	42.4	34.7
80T		142.7	[illegible]	4.5	41.8	34.7
81T		138.0	127.4	4.5	41.6	34.4
Avg.		141.1	[illegible]	4.5	41.9	34.6
82T	1000°F.	117.0	[illegible]	6.5	41.8	33.9
83T		119.5	[illegible]	7.5	42.0	34.9
84T		115.4	[illegible]	6.5	41.6	34.9
Avg.		114.0	[illegible]	6.8	41.7	34.6

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

TABLE XIX

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XI. [illegible]

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.*	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC Hardness Before Exposure	RC Hardness After Exposure
[illegible]	RT	175.0	135.5	11.0	41.1	34.0
[illegible]		174.2	135.0	15.0	41.3	33.2
[illegible]		175.3	135.2	12.0	41.0	33.3
Avg.		174.8	135.2	12.0	41.1	33.5
[illegible]	600°F.	144.8	114.9	7.0	41.8	33.0
[illegible]		147.9	119.6	5.0	41.8	33.5
[illegible]		144.8	116.9	5.0	41.9	34.7
Avg.		145.8	117.1	5.7	41.6	33.5
[illegible]	800°F.	136.2	122.9	7.0	42.0	34.6
[illegible]		140.1	[illegible]	5.0	41.5	33.0
[illegible]		135.9	120.3	5.0	41.0	33.7
Avg.		138.1	125.1	5.7	41.5	33.8
[illegible]	1000°F.	124.3	82.9	3.0	41.4	34.3
[illegible]		125.3	[illegible]	[illegible]	42.0	33.7
[illegible]		[illegible]	[illegible]	[illegible]	41.6	33.2
Avg.		124.7	[illegible]	[illegible]	41.7	33.7

TABLE XI

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

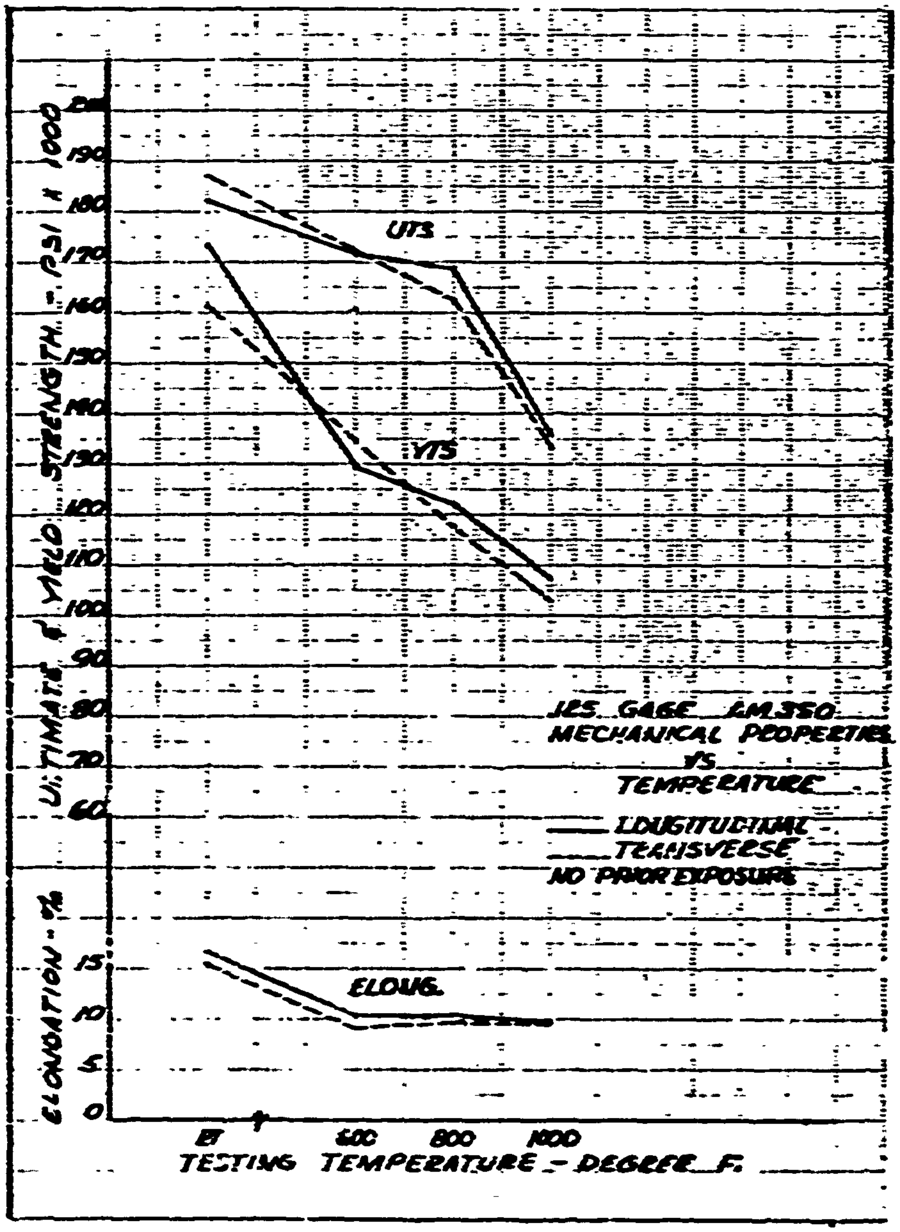

FIGURE 1

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

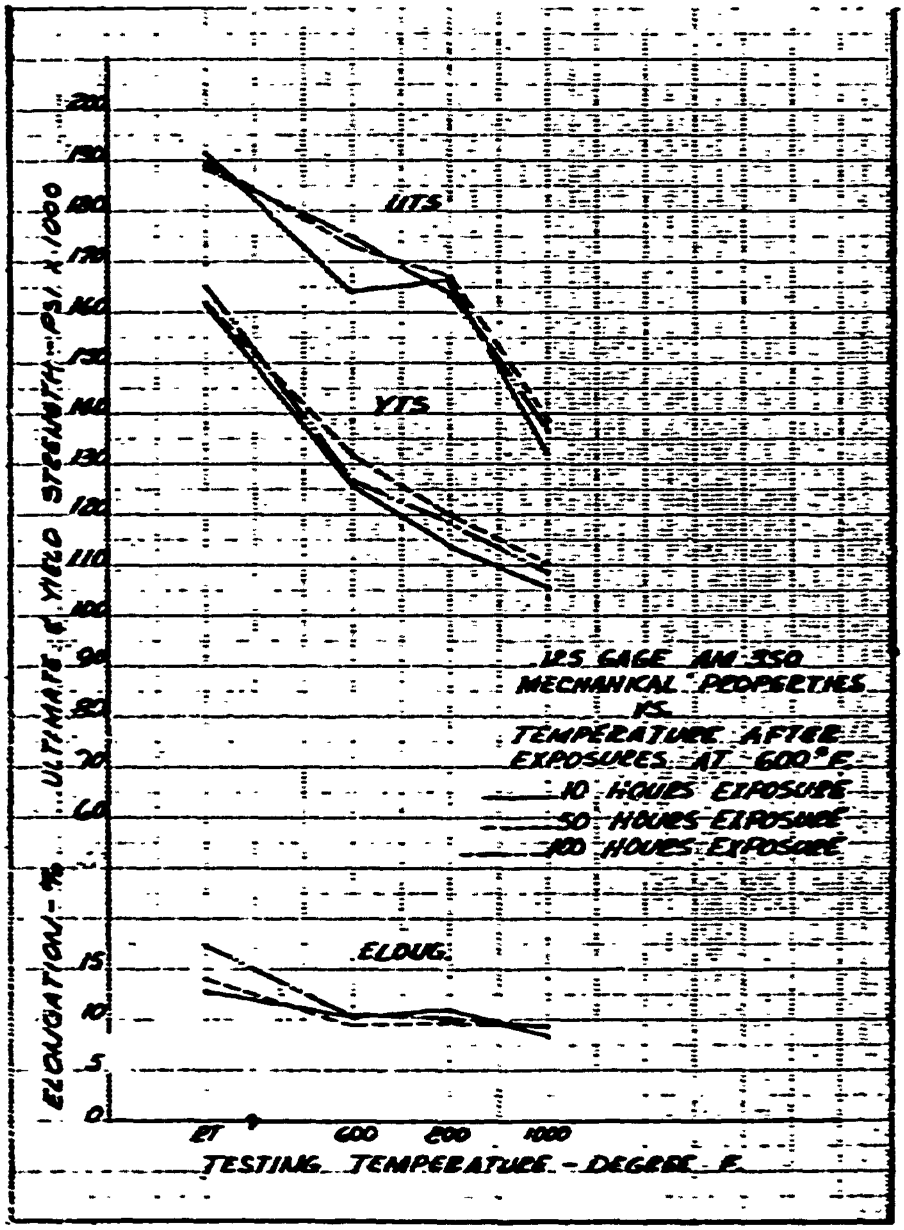

FIGURE 2

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

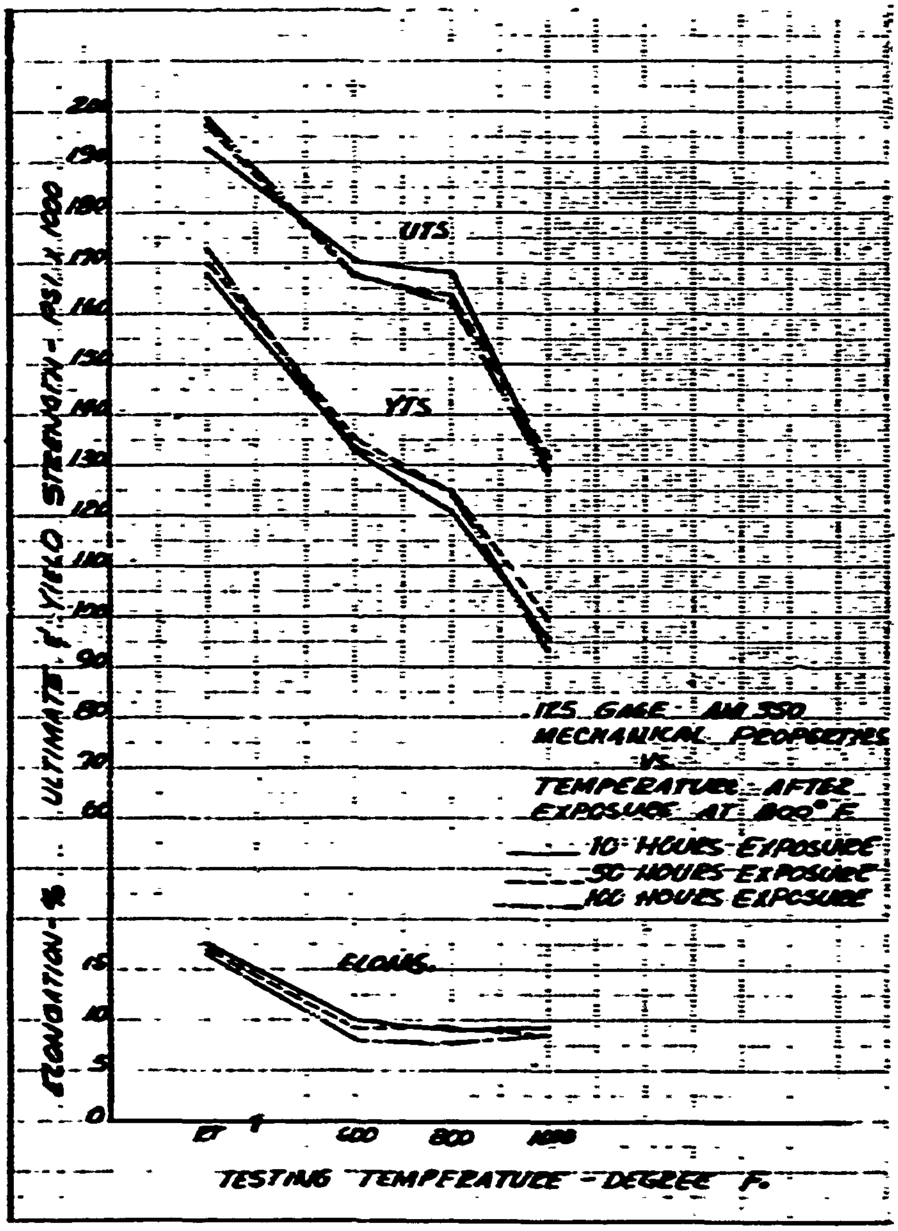

FIGURE 3

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

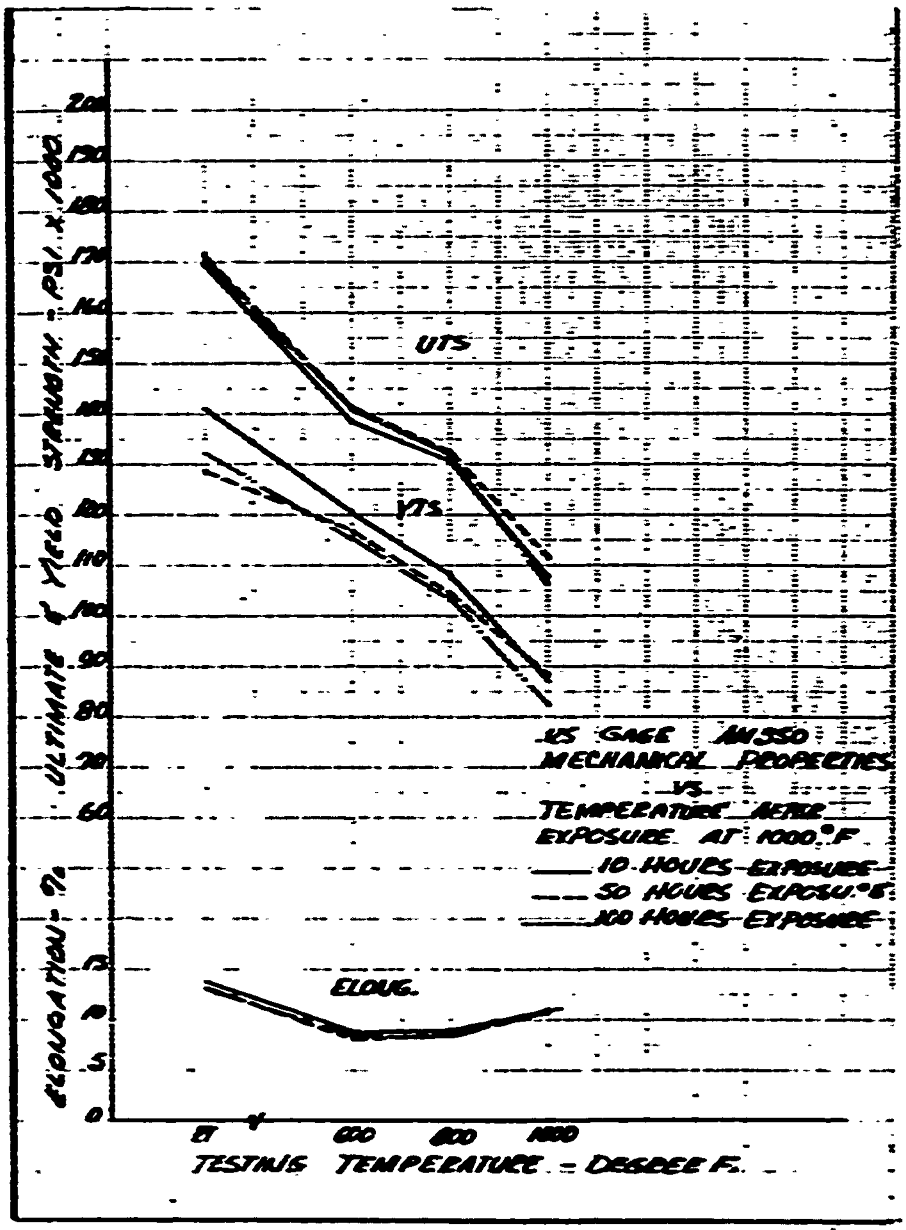

FIGURE 4

AUTHOR: G. Wadsworth DATE: 9-12-61 PAGE 26.

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

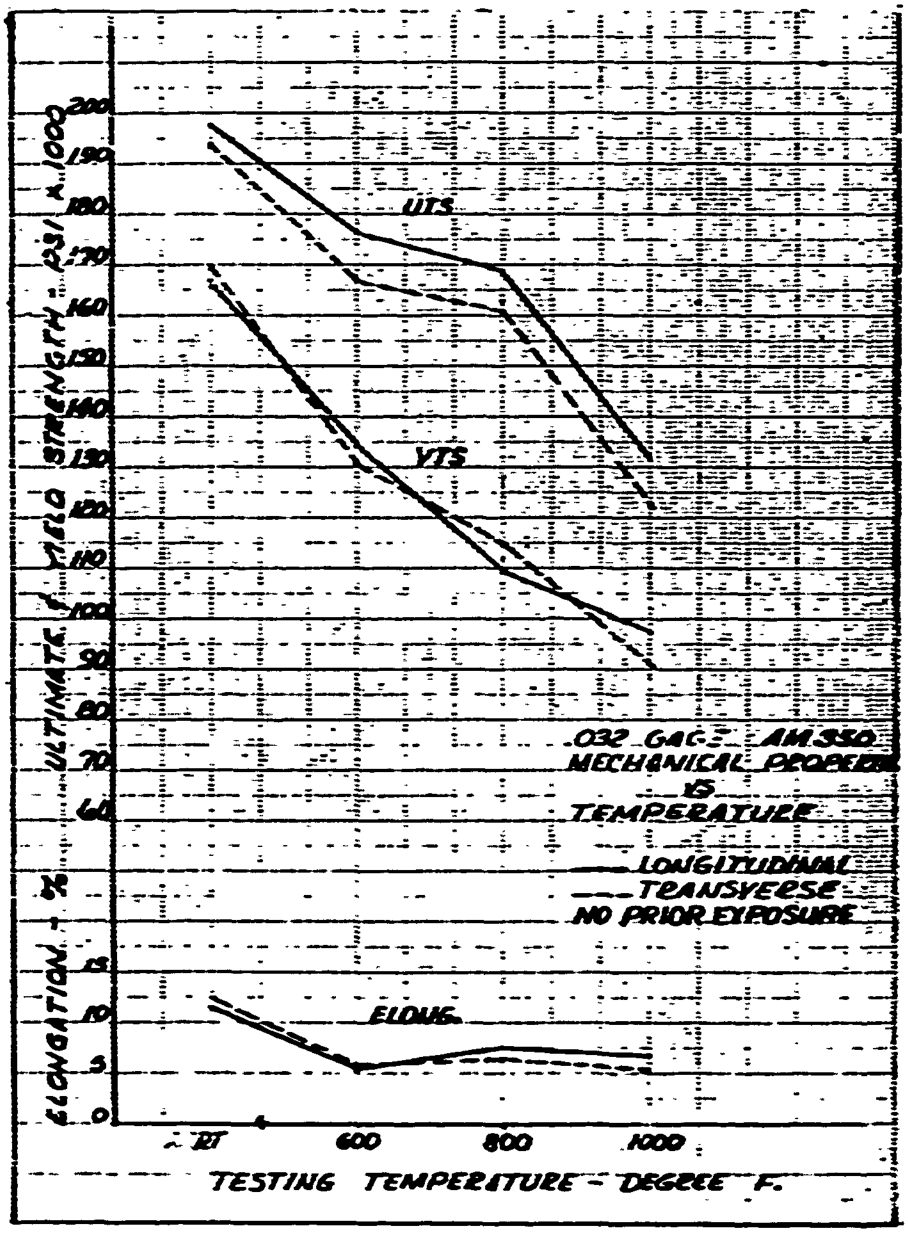

FIGURE 5

I. CATEGORY: Metals **CODE:** 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

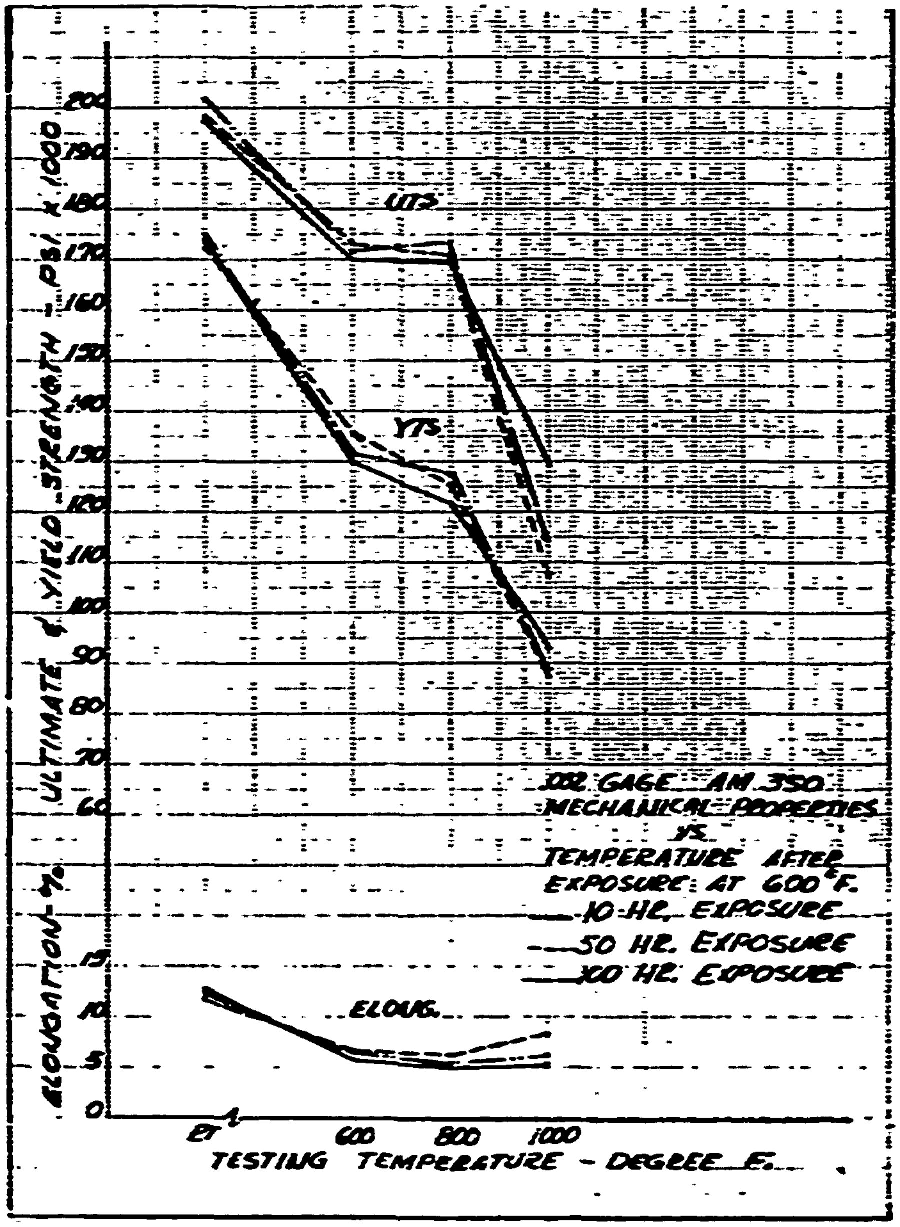

FIGURE 6

I. CATEGORY: Metals CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

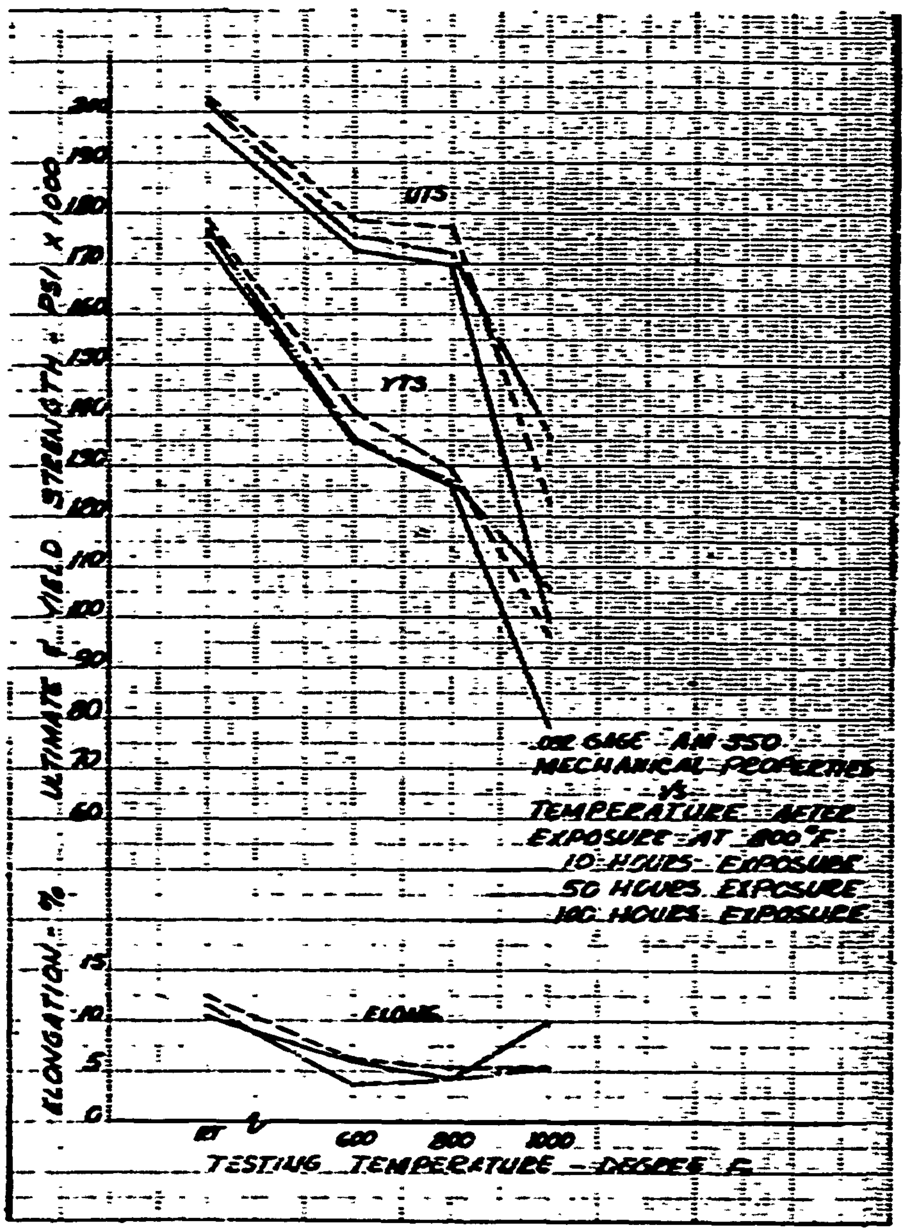

FIGURE 7

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals

CODE: 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

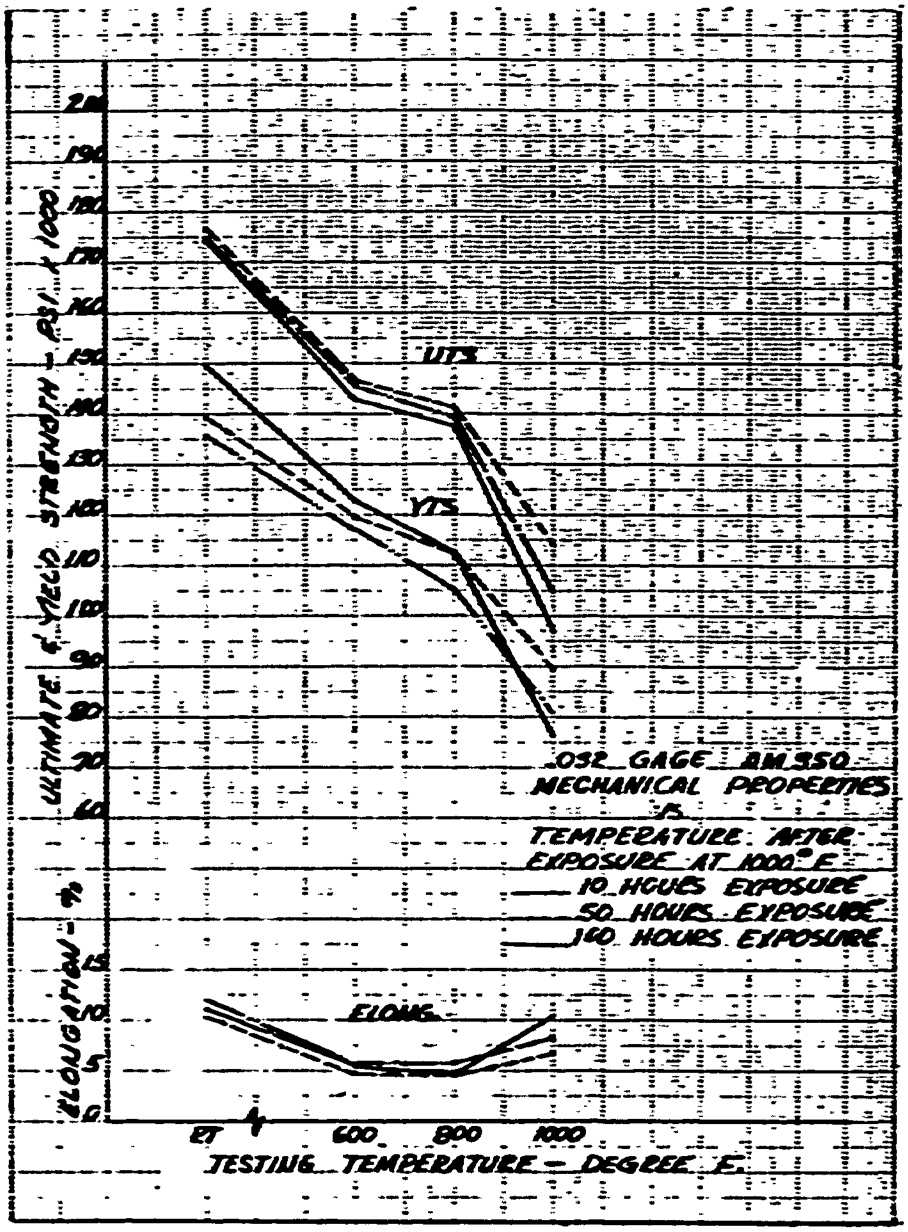

FIGURE 8

AUTHOR: G. Wadsworth

DATE: 9-12-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

AUTHOR: G. Wadsworth DATE: 9-12-61 PAGE [illegible].

MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Metals

CODE: 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

AUTHOR: G. Wadsworth

DATE: 9-12-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Metals **CODE:** 1-0-0

II. **MATERIAL NAME:** AM 350 Stainless Steel

VI. **RECOMMENDED USES:**

This alloy is recommended for use to 800°F in oxidizing or moderately corrosive environments where strengths to 200,000 psi are required.

VII. **SUPPLIERS AND TRADE NAMES:**

A. Suppliers

Allegheny-Ludlum - Others under licensing agreements.

B. Availability

Sheet, bar, plate and forging stock.

VIII. **REFERENCES:**

A. Materials and Process Job Report W-3-36, Investigation of Tensile Properties of AM 350.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Iron and Steel **CODE:** 1-8-1

II. **MATERIAL NAME:** Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

III. **GENERAL DESCRIPTION:**

The objective of this program was to determine if chemical etching and chemical milling will adversely affect the stress corrosion properties or promote intergranular attack on semi-austenitic PH steels.

IV. **DEVELOPMENTAL BACKGROUND:**

Future airborne and space vehicles will necessarily be made from heat resistant materials. Some of the materials currently being considered for these applications are semi-austenitic PH (precipitation hardening) steels. These steels are difficult to fabricate by conventional methods, especially on thin gauge sheets. The chemical milling of these steels would alleviate some of the fabrication problems if this milling does not adversely affect the other properties of these steels.

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AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Iron and Steel **CODE:** 1-8-1

II. **MATERIAL NAME:** Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

V. **PRINCIPAL PROPERTIES:**

A. **Mechanical**

1. Chemical milling does not cause intergranular attack or affect stress corrosion properties of semi-austenitic PH steels.

2. Chemical milling cuts in excess of 0.04 inch per side causes roughening of the surface on PH15-7Mo, 17-7PH and Vasco Jet 1000 steels in the fully heat treated condition.

I. CATEGORY: Iron and Steel CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The thermophysical properties of these chemical milled steels were not evaluated. However, there should be no difference in the thermophysical properties of chemical milled and mechanical milled parts.

I. CATEGORY: Iron and Steel CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties of these chemical milled steels were not tested but should not vary from those of mechanical milled parts.

I. CATEGORY: Iron and Steel CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

V. PRINCIPAL PROPERTIES:

D. Chemical

The chemical properties of these chemical milled steels were not tested but should vary only slightly from those of mechanical milled parts.

I. **CATEGORY:** Iron and Steel **CODE:** 1-8-1

II. **MATERIAL NAME:** Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

VI. **RECOMMENDED USES:**

Chemical milling could be used as a fabrication procedure for semi-austenitic PH steels. However, further investigation would be necessary to reduce the surface roughness resulting from milling these steels in the fully heat treated condition.

VII. **SUPPLIERS AND TRADE NAMES:**

The following companies are qualified to chemical mill these steels in the annealed condition only:

A. The Boeing Company
Seattle, Washington

B. Altemil Corporation
El Segundo, California

C. Anadite Corporation
South Gate, California

D. Straza Industries
El Cajon, California

E. Chemical Contour Corporation
Gardens, California

F. U.S. Chemical Milling Corporation
Manhattan Beach, California

VIII. **REFERENCES:**

A. Boeing Company Process Specification BAC 5759, Chemical Milling Steel.

B. Turco Products, Incorporated, Process Manual, Chem-Mill, Los Angeles, California.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

III. **GENERAL DESCRIPTION:**

The objective of this program was to qualify 6AL-4V titanium alloy fasteners for use on Boeing products.

IV. **DEVELOPMENTAL BACKGROUND:**

Titanium possesses several properties which make it very desirable for use on aerospace vehicles. The two main properties which are of interest to the aircraft industry are high strength and low density. The density of 6AL-4V titanium alloy is .161 pounds per cubic inch which is 40% less than steel, yet it is heat treatable above 95,000 psi shear. Therefore, steel fasteners can be replaced with titanium fasteners with no reduction in joint strength.

Titanium is also immune to corrosion in most oxidizing environments which is another desirable property.

The combination of these properties have led to much research, testing and usage in the aerospace industry.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Tensile - The ultimate tensile strength of titanium alloy (6Al-4V) fasteners is shown on Tables 13 through 29.

2. Double Shear - The ultimate double shear strength of titanium alloy (6AL-4V) fasteners is shown on Tables 18 through 29.

3. Tension - Tension Fatigue - The tension-tension fatigue life cycles at various loads of titanium alloy (6AL-4V) fasteners is shown on Tables 1 through 28.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - Rivet Hi-Shear, Flat Head, Interference Fit Titanium Alloy

Part No.: BAC B15BJ6-7
Supplier: Hi-Shear
Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD - POUNDS HIGH	FATIGUE LOAD - POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC WI	1	500	125	60,220	NF
								2			50,200	
								3			50,200	
								4			60,200	
								5			62,600	
								6			62,600	
								7	500	125	64,900	NF
							Ref.:	W-2-213				

TABLE 1

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61 PAGE 3.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" – Rivet Hi-Shear, 100° Head, Interference Fit, Titanium Alloy

Part No.: BAC R15HK6-8
Supplier: Hi-Shear Rivet Tool Company
Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR		
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS
Required =				Required =		

TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =					
BAC WL	1	500	125	48,000	C
	2			69,500	NF
	3			69,500	NF
	4			86,300	H
	5			86,300	NF
	6			111,900	C
BAC WL	7	500	125	68,100	NF

C = Collar Failure
NF = No failure
H = Head failure

Ref.: Fatigue Test of Titanium Fasteners W-2-[illegible]

TABLE 2

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys   **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - Rivet Hi-Shear, Flat Head, Inteference Fit, Titanium Alloy

Part No.: BAC R15BJ8-9
Supplier: Vol-Shan Mfg. Company

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC WL	1	900	200	60,000	NF
								2			60,000	
								3			60,400	
								4			60,400	
								5			65,400	
								6			65,400	
							BAC WL	7	900	200	64,700	NF

NF = No Failure

Ref.: Fatigue Test of Titanium Fasteners for Vendor Qualification M-2-213

TABLE 3

AUTHOR: Carole Eckhoff   DATE: 9-12-61   PAGE 5.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Rivet Hi-Shear, 100° Head, Interference Fit, Titanium Alloy

Part No.: BAC H153K10-20 Test Nut Used:
Supplier: Hi-Shear Mfg. Company Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC 41	1	1400	325	57,000	H
								2			58,800	C
								3			54,200	H
								4			60,400	NF
								5			65,400	NF
								6			65,400	NF
							BAC 41	7	1400	325	64,700	NF

H = Head failure
C = Collar failure
NF = No failure

Ref.: W2-213

TABLE 4

AUTHOR: Carie Eckhoff 02 DATE: 9-12-61 PAGE 6.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" - Rivet Hi-Shear, Flat Head, Interference Fit, Titanium Alloy

Part No.: BAC R15BJ12-17
Supplier: Vol-Shan Mfg. Company

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC W1	1	2000	500	60,200	NF
								2			60,200	NF
								3			60,000	NF
								4			60,000	NF
								5			60,200	NF
								6			60,200	NF
							BAC W1	7	2000	500	60,200	NF

NF = No Failure

Ref.: W-2-213

TABLE 5

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61 PAGE 7.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" - Rivet Hi-Shear, 100° Head, Interference Fit, Titanium Alloy

Part No.: BAC R15MK12-20 — Test Nut Used:
Supplier: Hi-Shear — Test Temperature: Ambient

STATIC TENSION					DOUBLE SHEAR				TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD	POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD	POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =					Required =				Required =					
									BAC ML	1	2000	500	61,500	NF
										2			61,500	
										3			60,200	
										4			60,200	
										5			61,700	
										6			62,300	
									BAC ML	7	2000	500	62,300	NF
									Ref., [illegible]2-213					

TABLE 6

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61 PAGE 8.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - Bolt-Lock, Shear, Flat Head Pull Type, Titanium Alloy

Part No.: BAC B30CZ8-10
Supplier: Vol-Shan
Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC WI	1	900	220	60,400	NF
							↕	2	↕	↕	60,400	↕
								3			60,100	
								4			60,100	
								5			60,300	
								6			60,300	
							BAC WI	7	900	220	60,300	NF
							Ref.: W-2-213					

TABLE 7

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Bolt-Lock, Tension, Flat Head, Stump Type, Titanium Alloy

Part No.: BAC B30SY10-16 Test Nut Used:
Supplier: Vol-Shan Mfg. Company Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC WI	1	3640	364	1,000,100	NF
								2			1,000,100	
								3			758,600	
								4			758,500	
								5			60,000	
								6			50,000	
							BAC WI	7	3540	354	60,000	NF
							Ref.: 6-2-223					

TABLE 8

AUTHOR: Ozzie Eckhoff DATE: 9-12-61

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Bolt-Lock, Shear, 100° Head, Stump Type, Titanium Alloy

Part No.: BAC B30BN10-13
Supplier: Vol-Shan

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							BAC WL	1	1400	325	33,800	H
								2			61,500	SP
								3			60,300	
								4			60,300	
								5			63,500	
								6			62,300	
							BAC WL	7	1400	325	62,300	HP
							Ref.:	T-2-213				

TABLE 9

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - "Hi-Lok" Fastener Assembly, 100° CSK Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HL11VPG-6-8
Supplier: Hi Shear

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
								1	1130	113	7,600	T
								2	1130	113	13,300	T
								3	1130	113	7,000	T
								4	950	95	532,000	T
								5	950	95	31,000	T
								6	950	95	40,000	T

TABLE 10

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Hi-Lok Fastener Assembly - 100°CSK Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HL11V70-10-12
Supplier: Hi-Shear

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
							Boeing Wichita	1	3280	328	3,000	H
								2	3280	328	3,000	
								3	3280	328	2,000	
								4	2300	230	15,000	
								5	2300	230	35,000	
								6	2300	230	31,000	
								7	1640	164	142,000	
								8	1640	164	173,000	
								9	1640	164	199,000	S
							Below Spec. 2° Angle Under Collar					
								1	2300	230	6,000	H
								2	2300	230	6,000	H
								3	2300	230	11,000	S

TABLE 11

AUTHOR: Gusie Eckhoff DATE: 9-12-61

I. **CATEGORY:** Light Metals and Alloys   **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt-Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 674V-10
Supplier: Vol-Shan

Test Nut Used:
Test Temperature: Ambient

Static Tension				Double Shear			Tension-Tension Fatigue					
Tested By	Specimen Number	Ultimate Load Pounds	Type of Failure	Tested By	Specimen Number	Ultimate Load Pounds	Tested By	Specimen Number	Fatigue Load Pounds High	Fatigue Load Pounds Low	Cycles to Failure	Type of Failure
Required =				Required =			Required =					
								1	2500	625	60,200	NF
								2			60,200	
								3			60,300	
								4			60,300	
								5			60,200	
								6			60,200	
								7	2500	625	60,100	NF

NOTE: These specimens were heat treated at 1700°F and had good microstructures

TABLE 12

AUTHOR: Ozzie Eckhoff OE   DATE: 9-12-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - "Hi-Lok" Fastener Assembly - Protruding Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HL10V70-6-6
Supplier: Hi-Shear

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	2040	C				Boeing Wichita	1	500	125	1,000,000	NF
	2	1940	C					2				
	3	1970	C					3				
	4	1900	C					4				
	5	1860	C					5				
	6	1940	C					6				
	7	1940	C					7	500	125	1,000,000	NF
	8	1840	C					8	1130	113	21,000	T
	9	1850	C					9	1130	113	8,000	
	10	1880	C					10	1130	113	13,000	
								11	950	95	52,000	
								12	950	95	59,000	
								13	950	95	105,000	
								14	564	56	315,000	
								15	564	56	236,000	T

TABLE 13

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

1/4" - "Hi-Lok" Fastener Assembly - Protruding Shear Head - (Titanium Pin-Aluminum Collar)

Part No.: HL10V70-8-8
Supplier: Hi-Shear

Test Nut Heads
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	3180	C				Boeing Wichita	1	900	220	1,000,000	NF
	2	3290	C					2				
	3	3300	C					3				
								4	900	220	1,000,000	NF
								5	2050	205	29,000	H
								6			12,000	T
								7			18,000	T
								8	2050	205	14,000	H
								9	1710	171	112,000	T
								10	1710	171	73,000	T
								11	1710	171	95,000	T
								12	1280	128	102,000	T
								13	1280	128	109,000	T

TABLE 14

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - "Hi-Lok" Fastener Assembly - 100°CSK Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HL11V70-8-10
Supplier: Hi-Shear

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	3260	C				Boeing Wichita	1	900	220	150,000	H
	2	3440	C					2	900	220	321,000	H
	3	3540	C					3	900	220	139,000	H
	4	3340	C					4	2050	205	31,000	H
								5	2050	205	50,000	T
								6	2050	205	36,000	H
								7	2050	205	9,000	H
								8	2050	205	289,000	T
								9	1710	171	31,000	H
								10	1710	171	114,000	T
								11	1710	171	176,000	T
								12	1710	171	73,000	H
								13	1710	171	36,000	H
								14	1710	171	18,000	H
								15	1280	128	627,000	T
								16	1280	128	2,002,000	NF
								17	1280	128	2,006,000	NF
								18	1280	128	259,000	T
								19	1280	128	2,211,000	NF
								20	1025	103	2,139,000	NF

TABLE 15

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" – Hi-Lok Fastener Assembly – Protruding Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HLGV70-10-10
Supplier: Hi-Shear

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	6050	C					1	1400	325	1,000,000	NF
	2	5850	C					2			1,000,000	NF
	3	6000	C					3			1,000,000	NF
	4	5950	C					4			1,000,000	NF
	5	5860	C					5			446,000	T
	6	5970	C					6			1,000,000	NF
	7	5880	C					7	1400	325	625,000	T
								8	3280	328	39,000	T
								9	3280	328	10,000	H
								10	3280	328	16,000	H
								11	2300	230	135,000	T
								12	2300	230	188,000	T
								13	2300	230	129,000	H
								14	1640	164	1,104,000	NF
								15	1640	164	1,564,000	NF

TABLE 16

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61 PAGE 18.

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

3/8" - Hi-Lok Fastener Assembly - Protruding Shear Head (Titanium Pin-Aluminum Collar)

Part No.: HL10V70-12 Test Nut Used:
Supplier: Hi-Shear Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
	1	8330	C				Boeing Wichita	1	2000	500	1,000,000	NF
	2	8440	C					2				
	3	8440	C					3				
	4	8470	C					4				
	5	8380	C					5				
	6	8450	C					6				
	7	8340	C					7	2000	500	1,000,000	NF

TABLE 17

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

1/4" - Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: KAS674V-10
Supplier: Vol-Shan

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	6,650		Boeing Wichita	1	10,150	Boeing Wichita	1	2500	625	63,300	KF
	2	6,730			2	10,000		2			63,300	T
	3	6,310			3	9,800		3			60,800	KF
	4	6,360			4	9,600		4			60,800	
	5	6,700			5	10,200		5			60,100	
	6	6,710			6	9,950		6			62,500	
	7	6,550			7	10,250		7	2500	625	122,800	KF
	Avg	6,573			Avg	9,993						

NOTE: These specimens fabricated from over heated rod stock and solution heat treated at 1750°F. They contained large prior beta grains.

TABLE 13

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 6747-10
Supplier: Vol-Shan

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	6510		Boeing Wichita	1	9,750	Boeing Wichita	1	2500	625	60,300	NF
	2	6920			2	10,150		2			60,300	
	3	673			3	10,200		3			60,300	
	4	6710			4	10,150		4			60,300	
	5	6800			5	10,300		5			60,800	
	6	6430			6	9,950		6			60,800	
	7	6460			7	10,100		7	2500	625	60,300	NF
	Avg.	6651			Avg.	10,086						

NOTE: These specimens were solution heat treated at 1800°F. They contained large prior beta grains.

TABLE 19

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS6757-10 (5/16" dia.)
Supplier: Hi-Shear
Test Nut Used: Fatigue NAS 679-45; Tensile BAC N10B-054
Test Temperature:

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	10,250	Not Recorded	Boeing Wichita	1	15,000	Boeing Wichita	1	4,040	1,010	570,000	Not Recorded
	2	10,700			2	15,100		2			216,000	
	3	10,600			3	15,150		3			385,000	
	4	10,300			4	15,000		4			607,500	
	5	10,500			5	15,400		5			198,200	
	6	10,400			6	14,850		6			542,600	
	7	10,500			7	15,300		7	4,040	1,010	191,400	
	Avg.	10,454			Avg.	15,077				Avg.	364,185	
	Ref.:	W-2-359										

TABLE 20

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 676V-12 (3/8" dia.)
Supplier: Hi-Shear Rivet & Tool Co.

Test Nut Used: Fatigue NAS 679-A6; Tensile BAC N10B-064
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	15,250	Not Recorded	Boeing Wichita	1	21,200	Boeing Wichita	1	6,200	1,550	269,500	Not Recorded
	2	15,000			2	21,100		2			211,100	
	3	15,100			3	21,200		3			144,700	
	4	14,900			4	21,150		4			221,800	
	5	15,300			5	21,500		5			199,300	
	6	14,700			6	21,350		6			286,500	
	7	15,000			7	21,600		7	6,200	1,550	254,600	
	Avg.	15,036			Avg.	21,300		Avg.			226,785	

Ref.: M-2-359

TABLE 21

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

7/16" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 677V-21
Supplier: Vol-Shan

Test Nut Used:
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
BAC Wl	1	20,300	Not Recorded	BAC Wl	1	29,000	Boeing Wichita	1	8,400	2,100	35,000	T
	2	20,800			2	28,900		2			43,000	T
	3	19,300			3	29,400		3			50,000	T
	4	20,800			4	28,100		4			47,000	T
	5	20,440			5	30,400		5			60,000	NF
	6	19,680			6	29,300		6			32,000	T
	7	20,206			7	29,357		7	8,400	2,100	23,000	T
	Avg.	20,206			Avg.	29,357						
	Ref.:	Q.C. Laboratory Report Q-13118, dated 1-28-58										

TABLE 22

AUTHOR: Ozzie Eckhoff OE DATE: 9-12-61 PAGE 21.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

7/16" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 677V-23
Supplier: Vol-Shan

Test Nut Used: [illegible]
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	20,200		Boeing Wichita	1	28,600	BAC WI	1	8400	2100	42,900	T
	2	20,500			2	29,100		2			11,700	H
	3	17,800			3	29,800		3			60,200	NF
	4	19,400			4	29,500		4			60,200	NF
	5	20,400			5	29,600		5			60,200	NF
	6	20,160			6	29,200		6			65,100	T
	7	20,066			7	29,475		7	8400	2100	60,100	NF
	Avg.	20,066			Avg.	29,475						
	Ref.	G-4615			Ref.	G-4615		T = Thread Failure				
								Ref.	M-2-2[illegible]3			

TABLE 23

65

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

1/2" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)

Part No.: NAS 678V-16
Supplier Vol-Shan

Test Nut Used: Fatigue NAS 1021-AB; Tensile BAC N10B-080
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	28,900	Not Recorded	Boeing Wichita	1	40,900	Boeing Wichita	1	11,400	2,850	182,000	Not Recorded
	2	28,800			2	40,400		2			99,000	
	3	28,650			3	38,300		3			63,000	
	4	28,250			4	40,000		4			79,000	
	5	28,250			5	38,900		5			78,000	
	6	28,300			6	39,950		6			37,000	
	7	28,200			7	40,200		7	11,400	2,850	38,000	
Avg.		28,471			Avg.	39,807				Avg.	82,286	
	Ref.:	W-2-319										

TABLE 24

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Tension, 100° Head, Pull Type, Titanium Alloy

Part No.: BAC B30[illegible]-8-8 Test Nut Used: NAS 1080
Supplier: Vol-Shan Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	4,530	Not Recorded	Boeing Wichita	1	10,050	Boeing Wichita	1	2330	233	173,000	Not Recorded
	2	4,420			2	10,225		2			375,000	
	3	4,120			3	9,950		3			530,000	
	4	4,550			4	10,300		4			545,000	
	5	4,870			5	10,200		5			474,000	
	6	4,280			6	9,900		6			240,000	
	7	4,570			7	10,150		7	2330	233	174,000	
	Avg.	4,477			Avg.	10,112				Avg.	358,714	
	Ref.:	W-2-319										

TABLE 25

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Tension, Pan Head, Pull Type, Titanium Alloy

Part No.: BAC B30MB-8
Supplier: Vol-Shan

Test Nut Used: NAS 1080-C8
Test Temperature: Ambient

STATIC TENSION				SINGLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	4,680	Not Recorded	Boeing Wichita	1	10,000	Boeing Wichita	1	2330	233	73,000	Not Recorded
	2	4,950			2	10,450		2			75,000	
	3	4,860			3	9,800		3			66,000	
	4	4,610			4	10,250		4			61,000	
	5	4,460			5	10,500		5			87,000	
	6	4,810			6	10,400		6			106,000	
	7	4,770			7	10,400		7	2330	233	112,000	
	Avg.	4,734			Avg.	10,257				Avg.	82,857	
	Ref.:	W-2-319										

TABLE 26

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Shear, Flat Head, Pull Type, Titanium Alloy

Part No.: BAC B30CT8-8
Supplier: Vol-Shan

Test Nut Used: Fatigue NAS 1080; Tensile NAS 1080-C8
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	3,460	Not Recorded	Boeing Wichita	1	9,200	Boeing Wichita	1	1250	125	62,000	Not Recorded
	2	3,250			2	10,350		2			86,000	
	3	3,260			3	10,000		3			90,000	
	4	3,470			4	10,100		4			42,000	
	5	3,240			5	10,100		5			47,000	
	6	3,270			6	9,400		6			20,000	
	7	3,310			7	9,800		7	1250	125	33,000	
	Avg.	3,323			Avg.	9,850				Avg.	61,429	
	Ref.:	W-2-319										

TABLE 27

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, 100° Head, Pull Type, Titanium Alloy

Part No.: BAC 1330C28-10
Supplier Vol-Shan

Test Nut Used: NAS 1080-C8
Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS HIGH	FATIGUE LOAD POUNDS LOW	CYCLES TO FAILURE	TYPE OF FAILURE
Required =				Required =			Required =					
Boeing Wichita	1	3,600	Not Recorded	Boeing Wichita	1	10,200	Boeing Wichita	1	1250	125	78,000	
	2	3,610			2	10,200		2			74,000	
	3	3,520			3	10,050		3			2,234,000	
	4	3,520			4	10,050		4			53,000	
	5	3,550			5	10,200		5			63,000	
	6	3,710			6	10,250		6			307,000	
	7	3,640			7	10,050		7	1250	125	2,942,000	
	Avg.	3,573			Avg.	10,143				Avg.	825,714	
	Ref.	W-2-319										

TABLE 28

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" Bolt - Lock, Tension, 100° Head, Pull Type, Titanium Alloy

Part No.: - SAC B30EX10-13
Supplier: Voi-Shan

Test Nut Used:
Test Temperature: Ambient

Static Tension				Double Shear			Tension-Tension Fatigue					
Tested By	Specimen Number	Ultimate Load Pounds	Type of Failure	Tested By	Specimen Number	Ultimate Load Pounds	Tested By	Specimen Number	Fatigue Load Pounds High	Fatigue Load Pounds Low	Cycles to Failure	Type of Failure
Required =				Required =			Required =					
Boeing Wichita	1	6,530	Not Recorded	Boeing Wichita	1	16,400						
	2	6,720			2	15,200						
	3	6,520			3	15,880						
	4	6,600			4	15,800						
	5	6,790			5	15,300						
	6	6,680			6	15,580						
	7	6,480			7	15,700						
	Avg.	6,619			Avg.	15,837						
	Ref.	Q.C. Laboratory Report Q-12803, dated 12-31-57			Ref.	Same as tension.						

TABLE 29

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6Al-4V)

V. **PRINCIPAL PROPERTIES:**

D. Chemical

The composition of 6AL-4V titanium alloy by percent weight is as follows:

Aluminum	5.0 - 7.0
Vanadium	3.5 - 4.5
Carbon	.10 Max.
Iron	.30 Max.
Nitrogen	.07 Max.
Oxygen	.20 Max.
Hydrogen	.0175 Max.
Others	.40 Max
Titanium	Remainder

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-1

II. **MATERIAL NAME:** Titanium Fasteners (6AL-4V)

VI. **RECOMMENDED USES:**

6AL-4V titanium alloy fasteners are recommended for airframe usage where:

a. High strength fasteners are required along with minimum weight;

b. high strength fasteners are required in a high corrosive environment;

c. high strength non-magnetic fasteners are required;

d. any combination of the above three are required.

VII. **SUPPLIERS AND TRADE NAMES:**

Suppliers of 6AL-4V titanium alloy fasteners are as follows:

Hi-Shear Rivet and Tool Company
Voi-Shan Manufacturing Company
CamCar Screw and Manufacturing Company
Standard Pressed Steel Company

VIII. **REFERENCES:**

A. Boeing-Wichita Materials and Process Unit Report W-2-181K, Fatigue Test of Titanium Fasteners, dated November 1957.
B. Boeing-Wichita Materials and Process Unit Report W-2-213, Fatigue Test of Titanium Fasteners for Vendor Qualification, dated November 1957.
C. Boeing-Wichita Quality Control Laboratory Report Q-13148, dated 28 January 1958.
D. Boeing-Wichita Quality Control Laboratory Report Q-10803, dated 31 December 1957.
E. Boeing-Wichita Materials and Process Unit Report W-2-319, Qualification Tests of 6AL-4V Titanium Fasteners Manufactured by Voi-Shan Manufacturing Company, dated April 1959.
F. Boeing-Wichita Materials and Process Unit W-2-215, Evaluation of a Special Group of Voi-Shan Titanium Fasteners, dated November 1957.
G. Boeing-Wichita Quality Control Laboratory Report Q-4615, dated 30 September 1957.
H. Boeing-Wichita Materials and Process Unit Report W-2-359, Qualification Tests of NAS675V-10 and NAS676V-12 6 AL-4V Titanium Fasteners, dated November 1959.
I. Boeing Procurement Specification for Titanium Alloy Fasteners, BAC B30HR.
J. Boeing-Wichita Preliminary Report on Evaluation Tests of Titanium Hi-Lok Fasteners, dated 27 June 1958.

AUTHOR: Ozzie Eckhoff OE **DATE:** 9-12-61 **PAGE** 35.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys

CODE: 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

III. GENERAL DESCRIPTION:

The objective of this program was to determine the feasibility of depositing aluminum by the vacuum plating technique.

IV. DEVELOPMENTAL BACKGROUND:

There are several attractive advantages of aluminum as a protective coating. Aluminum is anodic to most metals and thereby would be sacrificially protective to the basis metal. Aluminum is itself corrosion resistant. A corrosion protective coating of aluminum applied by the vacuum method would eliminate the problems of hydrogen embrittlement and excessive heating of the basis metal required by flame spraying. Thin films of aluminum are common but are known to be porous. As a protective coating, aluminum would be required to be substantially thicker. Aluminum can be electroplated but relatively thick coatings are difficult to obtain. No published literature is available on a method to sustain vacuum plating to produce thick films.

AUTHOR: T. G. Kozan TGK. DATE: 9-1-61 PAGE 1

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Thin films of aluminum on smooth surfaces are bright and highly reflective.
2. Accurate control of thickness of thin films can be accomplished.
3. Thin films in the order of 5-10 millionths of an inch have very good covering power.
4. Thin films are porous exhibiting rather extensive very small pin holes.
5. The cleanliness of the surface to be plated with thin films is very important to produce sound coatings.
6. Thick coatings of aluminum on the order of .0001 inch lose brightness and become matte in appearance regardless of the surface of the substrate.
7. A light, dry grit blasting of metallic surfaces, just prior to vacuum deposition is necessary to provide satisfactory adhesion of thick aluminum deposits.
8. Vacuum deposited aluminum appears to be porous in thickness up to .003 inch.
9. Line of sight coverage is very apparent in plating with aluminum. Reverse sides of specimens plated received little or no plating.
10. Thick deposits are crystaline and are brittle.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

B. Thermophysical

No information is available on the elevated temperature properties of thin films of aluminum. The wide difference in the coefficient of thermal expansion of aluminum and most metal substrate presents serious problems of adhesion. Aluminum deposits .002 inch thick on grit blasted molybdenum exhibited good adhesion to room temperature bend-fracture test and temperature to approximately 1000°F. Near the melting point of aluminum, severe blistering of the aluminum occurred. Diffusion bonding was not apparent after short time heat treatment aging at 1000°F.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties were not investigated in this work. It was assumed that these properties would closely correspond to the bulk metal properties. It should be pointed out that the vacuum plated aluminum is porous and as a result, the electrical properties such as resistivity could vary slightly from the bulk metal

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

V. **PRINCIPAL PROPERTIES:**

D. Chemical

The chemical properties were not investigated in this work. The production of vacuum deposits, methods of sustaining plating to accomplishing thick deposits were directed toward high temperature oxidation protection. Adhesion difficulties prevented extensive studies of oxidation protection.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-7-9

II. **MATERIAL NAME:** Vacuum Plated Aluminum

VI. **RECOMMENDED USES:**

Until satisfactory surface preparation and/or methods of diffusion bonding are determined, no recommendation can accurately be given.

VII. **SUPPLIER AND TRADE NAME:**

None

VIII. **REFERENCES:**

A. Materials and Process Job Report F-1-1, Vacuum Deposition of Metals.

B. Materials and Process Job Report F-3-15, Laminated Refractory Electro-deposits as High Temperature Protection of Molybdenum.

C. Vacuum Deposition of Thin Films, L. Holland - Boeing Library - T.S. 213H 735 v.

AUTHOR: T. G. Kozan DATE: 9-11-61 PAGE 6.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

III. **GENERAL DESCRIPTION:**

The objective of this program was the evaluation of alkaline etch cleaning prior to Alodizing or Anodizing aluminum for potential increased salt spray resistance. The scope included in the testing of materials which were etch cleaned in comparison to materials which were not etch cleaned.

IV. **DEVELOPMENTAL BACKGROUND:**

Alkaline etch cleaning of machined 7178 aluminum alloy gives added protection to parts that have been Alodined. This has been indicated by improved salt spray resistance tests and fewer corrosion problems experienced in the shop since Alkaline cleaning was inaugurated.

WHK

AUTHOR: W. H. Holins DATE: 9-13-61 **PAGE 1.**

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

A. Mechanical

These materials were not investigated from this standpoint as there existed no need under this program.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

These materials were not investigated from this standpoint as there existed no need under this program.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. **PRINCIPAL PROPERTIES:**

C. Electrical

These materials were not investigated from this standpoint as there existed no need under this program.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

D. Chemical

Chemical properties are depicted by following Tables I through VI and panels shown in Photographs EW-159340 and EW-159341. Based upon these characteristics, recommendations are made in Section VI of this report.

WHR

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

SALT SPRAY RESISTANCE TESTS - ALODINED AND ANODIZED ALUMINUM ALLOY PANELS

PROCESSED AT WICHITA DIVISION

Alloy	Processing Per BAC Specification Wichita Division	Wichita Salt Spray No.	Wichita Salt Spray Witec Eval.	Aero-Space Salt Spray No.	Aero-Space Salt Spray Aero-Space Eval.
7178 Machined	Alodine	1	Fail	1-S	Fail
7178 Machined	Alkaline Etch Clean - Alodine	2	Pass	2-S	Marginal
7178 Machined	Alkaline Etch Clean - Zyglo - Shot Peen - Alodine	3	Pass	3-S	Pass
7178 Machined	Anodize	6	Fail	6-S	Marginal
7178 Machined	Alkaline Etch Clean - Anodize	7	Pass	7-S	Pass
7075 Rolled	Alodine	4	Pass	4-S	Pass
7075 Rolled	Alkaline Etch Clean - Alodine	5	Pass	5-S	Pass
7075 Rolled	Anodize	8	Pass	8-S	Pass
7075 Rolled	Alkaline Etch Clean - Anodize	9	Pass	9-S	Pass

TABLE I

WHR

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

[illegible] PANELS PROCESSED AT AERO-SPACE DIVISION - SALT SPRAY EVALUATION

AERO-SPACE PROCESSED - WICHITA SALT SPRAY					AERO-SPACE PROCESSED - AERO-SPACE SALT SPRAY				
Panel No.	Alloy	Treatment*	Aero-Space Eval.	Wichita Eval.	Panel No.	Alloy	Treatment*	Aero-Space Eval.	Wichita Eval.
A3	2024	1	Fail	Fail	A1	2024	1	Fail	Fail
A4	2024	1	Fail	Fail	A2	2024	1	Fail	Fail
A7	2024	2	Fail	Fail	A5	2024	2	Fail	Fail
A8	2024	2	Fail	Fail	A6	2024	2	Fail	Fail
B3	2024	3	Pass	Marginal	B1	2024	3	Pass	Pass
B4	2024	3	Pass	Fail	B2	2024	3	Marginal	Fail
B7	2024	4	Pass	Fail	B5	2024	4	Pass	Marginal
B8	2024	4	Pass	Pass	B6	2024	4	Pass	Marginal
C3	7075	1	Fail	Fail	C1	7075	1	Pass	Marginal
C4	7075	1	Fail	Fail	C2	7075	1	Pass	Marginal
C7	7075	2	Fail	Fail	C5	7075	2	Pass	Marginal
C8	7075	2	Pass	Fail	C6	7075	2	Pass	Marginal
D3	7075	3	Pass	Fail	D1	7075	3	Pass	Pass
D4	7075	3	Pass	Fail	D2	7075	3	Pass	Pass
D7	7075	4	Fail	Fail	D5	7075	4	Pass	Pass
D8	7075	4	Fail	Fail	D6	7075	4	Pass	Pass
E3	7178	1	Fail	Fail	E1	7178	1	Pass	Pass
E4	7178	1	Fail	Fail	E2	7178	1	Pass	Pass
E7	7178	2	Fail	Fail	E5	7178	2	Pass	Pass
E8	7178	2	Fail	Fail	E6	7178	2	Pass	Pass
F3	7178	3	Fail	Fail	F1	7178	3	Pass	Pass
F4	7178	3	Fail	Fail	F2	7178	3	Pass	Marginal
F7	7178	4	Fail	Fail	F5	7178	4	Pass	Marginal
F8	7178	4	Fail	Fail	F6	7178	4	Pass	Marginal

GENERAL NOTES: All panels were processed in the Manufacturing Shops' facilities and hot air dried per BAC 5719.

* 1. 5 Minutes Deoxidize, 3 Minutes Alodine
2. 5 Minutes Deoxidize, 5 Minutes Alodine
3. No deoxidize, 3 Minutes Alodine
4. No deoxidize, 5 Minutes Alodine

TABLE II

WHK

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ALODINE PANELS PROCESSED AT WICHITA - SALT SPRAY [illegible]

WICHITA PROCESSED - WICHITA SALT SPRAY					WICHITA PROCESSED - AERO-SPACE SALT SPRAY				
Panel No.	Alloy	Treatment*	Aero-Space Eval.	Wichita Eval.	Panel No.	Alloy	Treatment*	Aero-Space Eval.	Wichita Eval.
G3	2024	1	Pass	Pass	G1	2024	1	Pass	Pass
G4	2024	1	Pass	Pass	G2	2024	1	Pass	Pass
G7	2024	2	Pass	Pass	G5	2024	2	Pass	Pass
G8	2024	2	Pass	Pass	G6	2024	2	Pass	Pass
H3	2024	3	Pass	Pass	H1	2024	3	Pass	Pass
H4	2024	3	Pass	Pass	H2	2024	3	Pass	Pass
H7	2024	4	Pass	Pass	H5	2024	4	Pass	Pass
H8	2024	4	Pass	Pass	H6	2024	4	Pass	Pass
I3	7075	1	Pass	Pass	I1	7075	1	Pass	Pass
I4	7075	1	Pass	Pass	I2	7075	1	Pass	Pass
I7	7075	2	Pass	Pass	I5	7075	2	Pass	Pass
I8	7075	2	Pass	Pass	I6	7075	2	Pass	Pass
J3	7075	3	Pass	Pass	J1	7075	3	Pass	Pass
J4	7075	3	Pass	Pass	J2	7075	3	Pass	Pass
J7	7075	4	Pass	Pass	J5	7075	4	Pass	Pass
J8	7075	4	Pass	Pass	J6	7075	4	Pass	Pass
K3	7178	1	Pass	Pass	K1	7178	1	Pass	Pass
K4	7178	1	Pass	Pass	K2	7178	1	Pass	Pass
K7	7178	2	Pass	Pass	K5	7178	2	Pass	Pass
K8	7178	2	Pass	Pass	K6	7178	2	Pass	Pass
L3	7178	3	Pass	Pass	L1	7178	3	Pass	Pass
L4	7178	3	Pass	Pass	L2	7178	3	Pass	Pass
L7	7178	4	Pass	Pass	L5	7178	4	Pass	Pass
L8	7178	4	Pass	Pass	L6	7178	4	Pass	Pass

General Note: It was noted that the panels had very dark color and nearly all had some powder ranging from slight to very heavy. However, the normal immersion time for Alodine at Wichita is only two minutes. These panels were processed in the same manner as those in Aero-Space and per [illegible] 5719.

* 1. 5 Minutes Deoxidize, 3 Minutes Alodine.
2. 5 Minutes Deoxidize, 5 Minutes Alodine.
3. No Deoxidize, 3 Minutes Alodine.
4. No Deoxidize, 5 Minutes Alodine.

TABLE III

W.H.K.

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. **PRINCIPAL PROPERTIES:** (Continued)

D. Chemical (continued)

ANODIZE PANELS PROCESSED AT AERO-SPACE DIVISION - SALT SPRAY EVALUATION

AERO-SPACE PROCESSED - AERO-SPACE SALT SPRAY

Panel No.	Alloy	Anodize Cycle	Aero-Space Evaluation
F-1	2024	Short	Fail
F-2	2024	Short	Fail
F-6	2024	Long	Fail
S-1	7075	Short	Fail
S-2	7075	Short	Fail
S-5	7075	Long	Fail

AERO-SPACE PROCESSED - WICHITA SALT SPRAY

Panel No.	Alloy	Anodize Cycle	Wichita Evaluation
F-3	2024	Short	Border Line
F-4	2024	Short	Border Line
F-7	2024	Long	Acceptable
F-8	2024	Long	Acceptable
S-3	7075	Short	Failed
S-4	7075	Short	Failed
S-7	7075	Long	Failed
S-8	7075	Long	Failed

TABLE IV

WHK

AUTHOR: W. H. Kolins DATE: 9-13-61

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ANODIZED PANELS PROCESSED AT WICHITA DIVISION - SALT SPRAY EVALUATION

WICHITA PROCESSED - AERO-SPACE SALT SPRAY				WICHITA PROCESSED - WICHITA SALT SPRAY			
Panel No.	Alloy	Anodize Cycle	Aer.-Space Evaluation	Panel No.	Alloy	Anodize Cycle	Wibec Evaluation
C-3	2024	Short	Fail	C-1	2024	Short	Fail
C-4	2024	Short	Fail	C-2	2024	Short	Fail
C-7	2024	Long	Pass	C-5	2024	Long	Pass
C-8	2024	Long	Pass	C-6	2024	Long	Pass
F-3	7075	Short	Fail	F-1	7075	Short	Fail
F-4	7075	Short	Fail	F-2	7075	Short	Fail
F-7	7075	Long	Pass	F-5	7075	Long	Pass
F-8	7075	Long	Pass	F-6	7075	Long	Pass

TABLE V

WHK

I. CATEGORY: Light Metals and Alloys **CODE:** 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ANODIZED PANELS PROCESSED AT TRANSPORT DIVISION - SALT SPRAY EVALUATION

TRANSPORT PROCESSED - AERO-SPACE SALT SPRAY

Panel No.	Alloy	Anodize Cycle	Aero-Space Evaluation
Q-1	2024	Long	Fail
Q-2	2024	Long	Fail
Q-3	2024	Long	Fail
Q-4	2024	Long	Fail
R-1	7075	Long	Fail
R-2	7075	Long	Fail
R-3	7075	Long	Fail
R-4	7075	Long	Fail

TRANSPORT PROCESSED - WICHITA SALT SPRAY

Panel No.	Alloy	Anodize Cycle	Wichita Evaluation
Q-5	2024	Long	Pass
Q-6	2024	Long	Pass
Q-7	2024	Long	Pass
Q-8	2024	Long	Pass
R-5	7075	Long	Fail
R-6	7075	Long	Fail
R-7	7075	Long	Fail
R-8	7075	Long	Fail

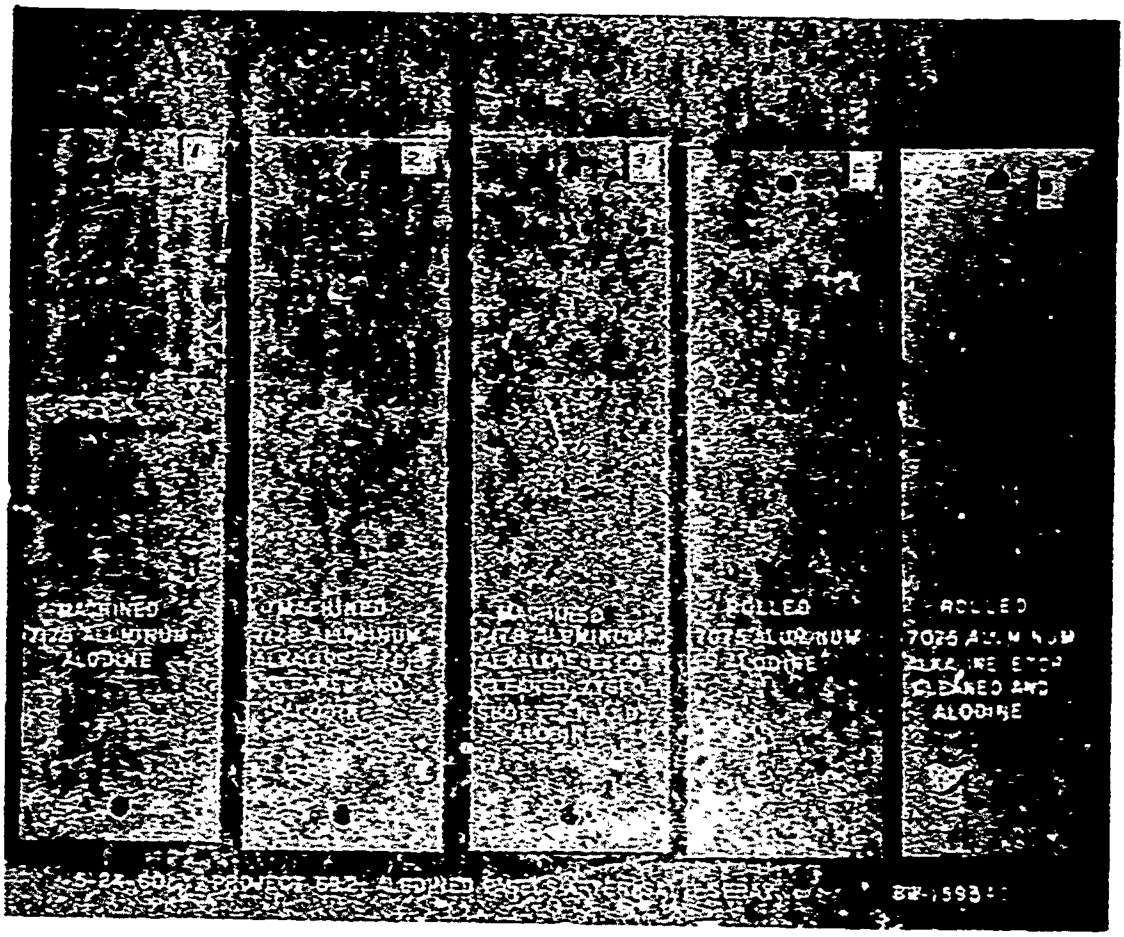
TABLE VI

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)



BW-159340

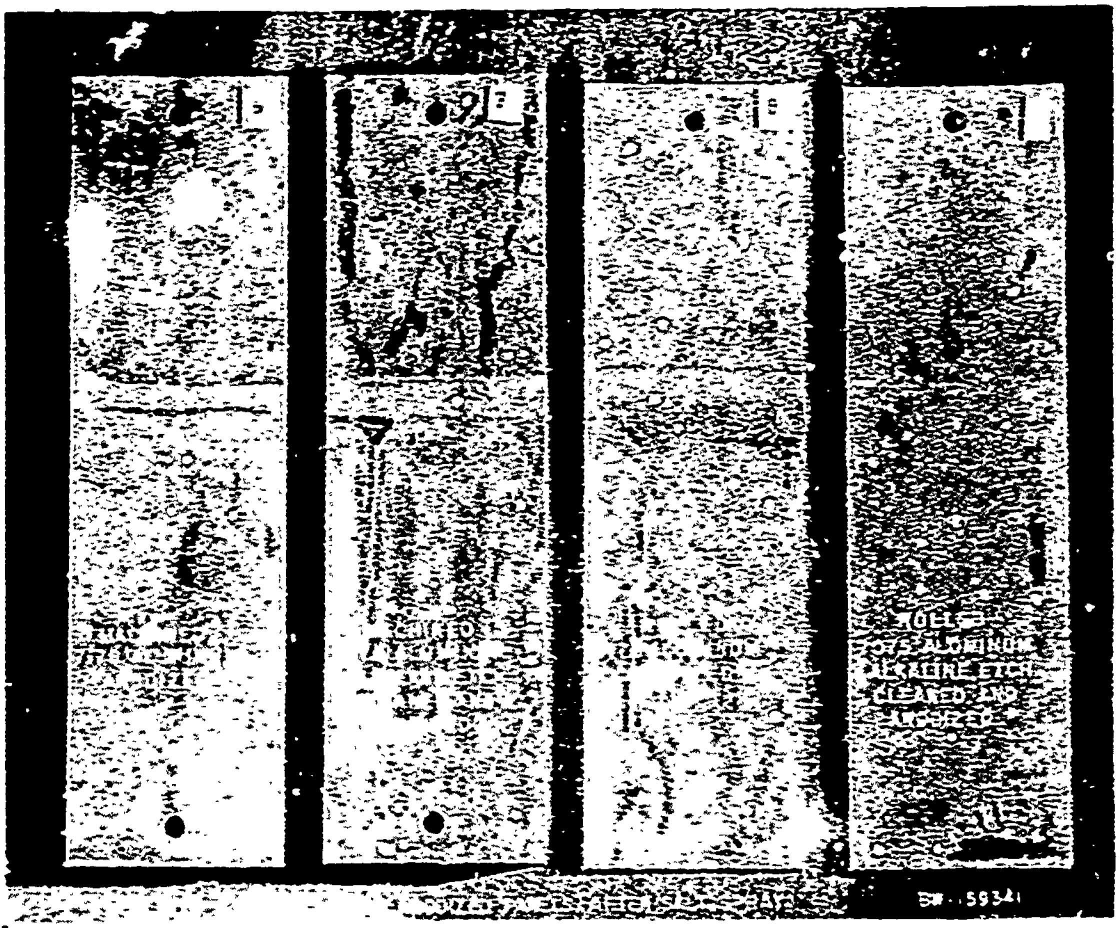
WHK

I. **CATEGORY:** Light Metals and Alloys   **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)



BW-159341

WHK

I. **CATEGORY:** Light Metals and Alloys **CODE:** 2-8-4

II. **MATERIAL NAME:** Corrosion Resistance of Various Aluminums

VI. **RECOMMENDED USES:**

It is recommended that all extensively machined 7178 aluminum alloys be etch cleaned prior to Alodine or Anodize processing. It is not recommended that rolled 7075 aluminum alloy be etch cleaned prior to Alodine.

VII. **SUPPLIERS AND TRADE NAMES:**

Not applicable.

VIII. **REFERENCES:**

A. Military Specification MIL-C-5541, "Chemical Films for Aluminum and Aluminum Alloys", and MIL-A-8625A, "Anodic Coatings for Aluminum Alloys and Aluminums".

B. Boeing-Wichita Manufacturing Research Report 68.2, "Salt Spray Resistance Tests, Anodized and Alodined Aluminum Alloy, Etched vs Non-Etched".

WHK

AUTHOR: W. H. Kolins DATE: 9-13-61 PAGE 14.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-7-9

II. **MATERIAL NAME:** Vacuum Plated Cadmium

III. **GENERAL DESCRIPTION:**

The purpose of this program was to investigate the properties of vacuum deposited cadmium plating, including corrosion resistance, adhesion of plate to base metal of steel and paint adhesion to vacuum deposited plate. A determination was made to detect any detrimental effect on the physical properties of AISI 4340 steel, heat treated 260,000 to 280,000 psi resulting from surface preparation and vacuum deposition of cadmium.

IV. **DEVELOPMENTAL BACKGROUND:**

Delayed brittle failures of stressed high strength steel parts have resulted from hydrogen pick up during electroplating sequences. A corrosion protective coating of cadmium applied by the vacuum method would eliminate the problem of hydrogen embrittlement associated with electrodeposited coatings. Since vacuum deposited coatings are more porous than electrodeposited coatings, the thickness requirements for adequate corrosion protection and a suitable surface preparation for adequate plate adhesion need to be established.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-7-9

II. **MATERIAL NAME:** Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Adhesion of Vacuum Deposited Cadmium to Base Metal of Steel.
   A light, dry grit blasting of the steel surface just prior to vacuum deposition is necessary to provide satisfactory adhesion of cadmium to steel.

2. Primer Adhesion to Vacuum Deposited Cadmium.
   Vacuum deposited cadmium receiving a chromate conversion coating, QQ-P-416A Type II, provides an adequate surface for good adhesion of zinc chromate primer.

3. Porosity.
   Vacuum deposited cadmium is inherently porous and requires a thicker deposit than electrodeposited cadmium to provide adequate corrosion protection.

4. Embrittlement.
   Cleaning, grit blasting and vacuum cadmium plating has no apparent effect on the tensile strength of 260,000 to 280,000 psi steel based on exposure to notched tensile tests.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-7-9

II. **MATERIAL NAME:** Vacuum Plated Cadmium

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

Information on the elevated temperature properties of this coating are not available. It is probable that this coating would present the elevated temperature properties identical with electroplated deposits. As a result this coating is not recommended for use on low alloy steels heat treated above 220,000 psi in environments of stress and temperatures above 500°F.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties were not investigated in this work since it was assumed that these properties would closely correspond to electroplated coatings. It should be pointed out that the vacuum plated cadmium is more porous and as a result the electrical properties such as resistivity could vary slightly from the solid metal.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-7-9

II. **MATERIAL NAME:** Vacuum Plated Cadmium

V. **PRINCIPAL PROPERTIES:**

D. Chemical

1. Corrosion Protection

a. Salt Spray

Vacuum deposited cadmium being more porous than electrodeposited cadmium offers less corrosion protection than an equal thickness of electrodeposited cadmium. However, a thickness of .0005 inch of vacuum deposited cadmium will withstand 240 hours in salt spray without appearance of red corrosion products.

Vacuum deposited cadmium .0005 inch thick, receiving a chromate conversion coating is equal in corrosion protection to an electrodeposited cadmium plate of equal thickness with chromate conversion coating.

b. Condensing Humidity

Vacuum deposited cadmium offers much less corrosion protection to a humid environment than an equal thickness of electrodeposited cadmium.

Vacuum deposited cadmium, .0005 inch thick, receiving a chromate conversion coating is equal in corrosion protection to electrodeposited cadmium of equal thickness with a chromate conversion coating.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-7-9

II. **MATERIAL NAME:** Vacuum Plated Cadmium

VI. **RECOMMENDED USES:**

Vacuum deposited cadmium at least .0005 inch thick with a subsequent chromate conversion coating is recommended as a corrosion and non-embrittling protective coating for high strength steel parts heat treated up to 280,000 psi, provided that the parts are given a light, dry grit blasting prior to vacuum deposition to provide good adhesion of the cadmium to the base metal.

VII. **SUPPLIERS AND TRADE NAMES:**

Suppliers meeting the requirements of MIL-C-8837, Coating, Cadmium, Vacuum Deposited, are available.

VIII. **REFERENCES:**

(1) MIL-C-8837, Coating, Cadmium, Vacuum Deposited.

(2) Boeing Document D3-1740, Properties of Vacuum Deposited Cadmium Plate on Steel.

(3) Boeing Test Report T2-1398, Effects of Plating Variables on Hydrogen Embrittlement of 220,000 to 240,000 psi Steels.

(4) Static Fatigue of High Strength Steel, R. H. Poring and J. A. Rinebolt, Transactions of the American Society for Metals, Vol. 48, 1956, pp 198-207.

(5) Wichita Materials and Process Job Report F-1-3, Vacuum Deposition of Metals.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

III. **GENERAL DESCRIPTION:**

The objective of this program was to determine the feasibility of electro-depositing soft ductile (gamma phase) manganese deposits and to determine if such deposits offer corrosion resistance protection for steel.

IV. **DEVELOPMENTAL BACKGROUND:**

There were several properties of manganese that prompted this investigation. Manganese is anodic to steel and should provide sacrificial corrosion protection and its higher melting point should extend the corrosion protection properties to a higher temperature range than the temperature ranges protected by zinc or cadmium deposits. Bright ductile (gamma phase) manganese can be deposited from either acid or alkaline baths. The oxidation of the manganous ion is a major problem during the deposition of ductile manganese deposits; this oxidation can be inhibited by the addition of a salt of a strong reducing acid (sodium hypophosphite) or a salt of a weak organic acid (sodium acetate).

A literature survey indicated that codeposition of copper (1%) or nickel (2%) stabilized manganese in the gamma phase. Copper was successfully codeposited with bright ductile manganese, but attempts to codeposit nickel gave either black deposits or deposits that were brittle.

Ductile manganese deposits up to .005 inches in thickness can be deposited and these deposits exhibit good resistance to salt spray and condensing humidity.

AUTHOR: E. N. Celestino DATE: 9-12-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Melting point - No tests were made to determine the melting points of these deposits.

2. Density - No tests were made to determine the density of the electroplated manganese deposits.

3. Coefficient of Expansion - No tests were made to determine the coefficient of expansion of the electrolytic manganese deposits.

4. Hardness - The manganese deposits were hard enough scratch 4130 steel but were not scratched by 4130 steel.

5. Surface Roughness - The manganese and the manganese copper deposits had the same surface roughness as the base metal on which they were plated.

6. Adhesion - The manganese and the manganese copper deposits had good adhesion properties on both copper and steel cathodes.

7. Ductility - Manganese and manganese copper deposits are very ductile.

8. Color - Manganese and manganese copper deposits are bright silver to matte grey in color.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

The thermophysical properties of manganese deposits have not been determined as no need for this data exists at this time.

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties of electrodeposited manganese have not been determined.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

V. **PRINCIPAL PROPERTIES:**

D. Chemical

1. Oxidation and Tarnish Resistance - Manganese and manganese copper deposits are subject to oxidation by atmospheric oxygen. Passivation of manganese deposits with chromic acid solutions inhibits oxidation and increases tarnish resistance.

2. Corrosion Protection - Manganese deposits have good corrosion protection properties on steel in salt spray and condensing humidity atmospheres.

3. Chemical Resistance - Manganese deposits are readily attacked by acid (inorganic or organic) solutions; concentrated chromium trioxide solutions passivate manganese deposits; and strong alkali solutions do not attack manganese.

AUTHOR: E. H. Celestine/mc DATE: 9-12-61

I. **CATEGORY:** Heavy Non-Ferrous Metals and Alloys **CODE:** 3-9-9

II. **MATERIAL NAME:** Electroplated Manganese

VI. **RECOMMENDED USES:**

There is not enough data available to warrant the recommendation of a use for electrodeposited manganese. It gives low temperature anodic protection to steel and should provide anodic protection at elevated temperatures.

VII. **SUPPLIERS:**

A. None

B. Availability - Not available

C. Costs - Undetermined

VIII. **REFERENCES:**

A. Materials and Process Job Report C-1-6, Ductile Manganese Plate

B. Materials and Process Job Report P-1-15, Electrodeposition of Manganese, Process Developments

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

III. GENERAL DESCRIPTION:

The objective of this program was to screen-test, by means of tensile shear test only, some of the most recently developed metal-to-metal bonding adhesives, and assess their potential value for manufacturing.

IV. DEVELOPMENTAL BACKGROUND:

It was believed that some of the newer adhesives might serve as replacements for some conventional fasteners in the fabrication of aircraft, thereby, resulting in lower production costs. Further, it is well known that European aircraft manufacturers have been employing metal bonding adhesives for structures in place of conventional fasteners, with considerable success and substantial reductions in manufacturing costs.

The scope of the program was to obtain from various vendors potentially available metal-to-metal adhesives which would produce maximum tensile shear values, and conduct an evaluation.

AUTHOR: L. M. Sherman Date: 9-11-61 PAGE 1

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics CODE: 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Heat cured adhesives appear to offer adequate strength and should be given wide consideration for Manufacturing concepts provided that further tests are accomplished toward proving specific materials for specific functions.

Mechanical Properties continued on following page entitled TABLE I.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

	Designation	Tensile-Shear Grand Average In psi	Remarks
1.	Armstrong Cork Company J-1154-E2	4000	Cured at 212°F for 2 hrs. This material no longer available.
2.	Armstrong Cork Co. J-1156-E30	3900	Cured at 180°F for 1-1/2 hr.
3.	Rubber & Asbestos Corp. M-611-CH60	3700	Cured at 340°F for 2-1/2 hrs.
4.	Armstrong Cork Co. J-1151-E15	3500	Cured at 212°F for 2 hrs.
5.	Reichhold Chemical Co. Experimental Material	3050	Cured at 350°F overnight.
6.	Armstrong Cork Co. J-1151-E2	2700	Cured at 212°F for 2 hrs.
7.	3M's EC-1469 Without Catalyst	2550	Cured at 350°F for 1 hr.

TABLE I

I. **CATEGORY:** Plastics CODE: 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

V. **PRINCIPAL PROPERTIES:**

C. Electrical

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

I. **CATEGORY:** Plastics   **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

V. **PRINCIPAL PROPERTIES:**

D. **Chemical**

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics   **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Heat Cured Metal Bonding Materials

VI. **RECOMMENDED USES:**

As a result of our investigative efforts, it was recommended that the heat cured metal-to-metal bonding adhesives, having a cure temperature of 212°F or below, be given further consideration for structural bonding of aircraft.

VII. **SUPPLIERS & TRADE NAMES:**

Armstrong Cork Co.	J-1154-E2 J-1156-E30 J-1151-E2 J-1151-E15
Rubber & Asbestos Corp.	M-611-CH60
Reichhold Chemical Co.	Experimental Material
3M's Company	EC-1469 without Catalyst

VIII. **REFERENCES:**

Boeing-Wichita, Manufacturing Research Report 78.1, "Adhesives - Metal-to-Metal Bonding Non-Military Aircraft and Commercial Applications".

AUTHOR: L. M. Sherman   Date: 9-11-61

I. CATEGORY: Plastics   CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

III. GENERAL DESCRIPTION:

The objective of this program was to determine by screen test, by means of tensile-shear test only, some of the most recently developed metal-to metal bonding adhesives, and to assess their potential value for Manufacturing.

IV. DEVELOPMENTAL BACKGROUND:

It was believed that some of the new adhesives might serve as replacements for some conventional fasteners in the fabrication of aircraft, thereby, resulting in lower production costs. Further, it is well known that European aircraft manufacturers have been employing metal bonding adhesives for structures in place of conventional fasteners with considerable success and substantial reductions in manufacturing costs.

The scope of the program was to obtain from various suppliers potentially available metal-to-metal adhesives which would produce maximum tensile shear values, and conduct an evaluation.

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Room Temperature Cured Adhesives

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

The following data supports the recommendation that room temperature cured adhesives not be used in manufacture of aircraft structures until materials possessing greater reliability and strength have been proven for specific applications.

See TABLE I for tensile shear data.

I. CATEGORY: Plastics CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

A. Mechanical

	Designation	Tensile-Shear Average In psi	Remarks
1.	3M's EC-1751 A & B	2400	Cured 7 Days.
2.	Armstrong Cork Co. J-1151-E1	2300	Cured 7 Days.
3.	Armstrong Cork Co. J-1156-E30	2100	Cured 7 Days.
4.	3M's EC-1468 A & B	2050	Cured 7 Days - No EC-1290 Primer used.
5.	Ren Plastics, Inc., RP-1250 with Hardener	1950	Cured 13 Days.
6.	a. Rubber & Asbestos Corp. M-688-CH16	1850	Cured 5 Days.
	b. Rubber & Asbestos Corp. M-611-CH16	1500	Cured 7 Days
7.	Armstrong Cork Co. J-1151-E9	200	Cured 7 Days
8.	a. Reichhold Chemical Co. Experimental Material	Less Than 100	5 Parts Compound A 3 Parts Compound B Cured 7 Days.
	b. Reichhold Chemical Co. New Experimental Material	1300	Supplier submitted a second sample. Compounded and cured same as a. above.
	c. Reichhold Chemical Co. New Experimental Material	2450	5 Parts Compound A 2 Parts Compound B Cured 7 Days.

ROOM TEMPERATURE CURED ADHESIVES - TENSILE-SHEAR DATA

TABLE I

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property has not been determined by Boeing-Wichita since there was no requirement for this information under the scope of this program.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Room Temperature Cured Adhesives

V. **PRINCIPAL PROPERTIES:**

C. Electrical

This property has not been determined by Boeing-Wichita since there was no requirement for this information under the scope of this program.

I. **CATEGORY:** Plastics **CODE:** 6-6-1

II. **MATERIAL NAME:** Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

D. Chemical

This property has not been determined by Boeing-Wichita since there was no requirement for this information under the scope of this program.

I. **CATEGORY:** Plastics **CODE:** 6-1

II. **MATERIAL NAME:** Various Room Temperature Cured Adhesives

VI. **RECOMMENDED USES:**

Since the room temperature cured adhesives produce a lower tensile shear value, it is recommended that these adhesives not be considered for use in the manufacture of aircraft structures until materials are advanced which possess superior reliability and strength.

VII. **SUPPLIERS & TRADE NAMES:**

3M	EC-1751 A & B and EC-1468 A & B
Armstrong Cork Co.	J-1151-E1 J-1156-E30 J-1151-E9
Ren Plastics, Inc.	RP-1250 with Hardener
Rubber & Asbestos Corp.	K-688-CH16 K-611-CH16
Reichhold Chemical Co.	Experimental Material New Experimental Material.

VIII. **REFERENCES:**

Boeing-Wichita, Manufacturing Research Report 78.1, "Adhesives - Metal-To-Metal Bonding Non-Military Aircraft and Commercial Application".

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

III. GENERAL DESCRIPTION:

The objective of this program was to determine capabilities and qualities of Paraplast #33 as an expendable mandrel material for use in the plastic laminate shop. It was felt that the material offered certain qualities for a mandrel material, i.e., it is prepared easily by casting, removed easily because of solubility in water and is capable of being remelted or broken, without damage to the laminated part.

IV. DEVELOPMENTAL BACKGROUND:

This program developed from a need for a mandrel material which possessed those qualities stated under III (above).

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Handling and Melting Equipment

Paraplast #33 is procured as a powder. It must be melted (melting point approximately 280°F) and an intermittent mixing operation must be performed. This necessitates heating from the outside of the container toward the interior of the Paraplast. If re-use of the Paraplast is planned, the mixture being heated may consist of both powder and crushed (to some degree) solid Paraplast as well as molten material. Contact of the molten material with the cooler powder or solid may result in a setting up of the molten material and consequent "balling up" of the mixture. This combination of requirements and events results in a complex heat transfer relationship that severely restricts possible design variations of the facility itself.

The pilot plant operation indicates a desirable pour temperature of 320°F ± 10°F. No fumes or vapors are given off, according to the supplier, unless the temperature is in excess of 470°F. Complete decomposition occurs around 1200°F and any heating facility design should make provisions to avoid local "hot spots" in the Paraplast mixture in excess of 480°F.

A steam heated chamber or melt pot has obvious characteristics which make it appear the most desirable method of heating because of the upper limit of temperature available from a given steam supply. This unit is more costly (from the fabrication standpoint) than an electrically heated unit so only brief mention will be made of the steam design. Equipment Engineering, Boeing-Wichita, designed a pot - Drawing P289-1578-ESC - calling for steam at 150 psi. This is a temperature (non-super heated) of approximately 358°F. The design calls for a temperature control valve for the Paraplast pour spout. This valve is essential and should be incorporated in any design actually fabricated (Nordstrom Plug Valve - wrench operated, flanged end, steam jacketed #2815, 1" I.D.).

In the pilot plant operation, a Glas-Col Apparatus Company Drum Heater with an 1800-watt bottom and a 6800-watt side capacity was procured and installed. It was completely unsatisfactory for this operation without modification. The heating element wires were too small, too thoroughly insulated (thermal) and too far from the heating surface. The bottom element burned out in less than 30 hours operating time

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1. (continued)

and the whole unit required exterior insulation application in order to be an effective heating installation.

A more reliable, effective and, it is felt, satisfactory unit can be in-Plant fabricated by forming a melting pot of 1/4" cold rolled steel and bolting strip type heating elements on the exterior of the steel pot. In order to avoid local hot spots at the interior of the pot, thermostat type temperature controllers should be located on the exterior surface of the pot and its contacts wired in series with the thermostat contacts actuated by the temperature of the molten Paraplast. This dual thermostat arrangement is inexpensive and protects against localized overheating and decomposition. In an electrical installation the Paraplast pour valve must be heated by means of an electric blanket-type heater. To date, a satisfactory valve and heater arrangement has been a Nordstrom Glas-Col Flash Heating Mantles (Catalog #0-108-1000 M1 for a 1" I.D. Valve). The mantles were fastened together with "hog ring" wire clips and the two elements connected in series across the 120-volt supply. No temperature control was found necessary as they reached thermal equilibrium at the desired pour temperature. Sketches indicating pot configuration, heater location, size, and control connections are shown in Figures 1 and 2.

Since the melt pot itself is located above floor level, some means such as a crusher-type screw conveyor is needed for returning the solid cooled Paraplast from the pour area back to the melting pot for remelt. This would be a must in volume operation.

Although the supplier indicates a "common propeller type agitator is sufficient for agitation", an agitator of this type does not, in our experience, accomplish agitation properly. A scraper type stirrer, rotating about one axis, with this axis in turn rotating about the center of the pot is the most desirable type arrangement. Commercial versions are available which are entirely supported by the drive motor. In the pilot plant operation, a scraper type with four dashers or blades rotates about the center of the pot. The assembly is supported by a bronze bushed thrust bearing mounted in a spider, resting on the bottom of the tank. The assembly rotates at 18 r.p.m., which is considered optimum for the arrangement; but the

I. CATEGORY: Plastics CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1. (continued)

wear and weight involved appear excessive and it is felt that 10 r.p.m. about each axis would be a desirable rotational speed (with the off-center type agitator).

The thermoswitch (based on Paraplast temperature) should be located two or three inches above the bottom of the pot (below the minimum level line) and so that it senses the temperature of the Paraplast mixture. Due to the agitator configuration this is something of a problem; the apparent solution appears to be to locate it as shown in Figure 1.

The exterior of the melting pot should be insulated as fully as possible.

2. Manufacturers Recommendations

a. Heat Conductivity and heat transfer in granular, liquid and solid forms.

The heat conductivity and heat transfer characteristics of Para-Plast products are essentially equal to those of water.

i.e. granular state = chopped ice, liquid state = water, solid state = solid ice.

b. Specific heat and latent heat of fusion.

The Specific Heat of Paraplast products is approximately .30 to .33 BTU per pound per °F in a solid state, and is approximately .35 to .38 BTU per pound per °F in a liquid state.

c. Special handling requirements (i.e., precautions) due to physically detrimental properties.

The handling requirements of liquid Paraplast products are the same as for any hot (excess of 300°F) low viscosity liquid, i.e., use face shields, gloves, etc. As previously pointed out, the heat transfer properties of Paraplast products are approximately the same as for water, consequently if splashed or spilled on the skin, severe burns could result. However, Paraplast products do not

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. c. (continued)

ordinarily stick, combine and adhere to the skin the way resinous type materials do. The immediate area in which liquid Paraplast products are used should be well ventilated and arranged in such a manner that in the event of accidental spillage - no contact between hot or liquid Paraplast and combustible materials such as wood, paper, solvents and the like would come about. Hot Paraplast, in most cases, can ignite combustible materials.

Paraplast products are balanced systems with "built-in" predetermined chemical equilibrium, stability, and contamination tolerance level - all based on the maximum practical "use life limit" of the product. In view of this, we again stress the point that modifications or additions of any other materials should not be attempted, as these modifications may disrupt the product in such a manner that considerable hazard and danger would result.

d. Toxicity while: (1) granular, (2) liquid and (3) solid.

(1) While granular, an amount of dust may be created from handling, similar to plaster and plaster type materials. The toxicity while in granular form is also of the same order as plaster.

(2) In a liquid state, no noticeable fumes or vapors are given off unless the temperature of the liquid Paraplast product is raised in excess of 150° F over the specification temperature, however, due to small amounts of contamination from use, handling etc., that inevitably get into every product used in this manner, small amounts of vapor or volatiles may be created. These vapors are usually not visually noticed, consequently, a "well-ventilated" area is strongly recommended for using all Paraplast products while in a liquid state.

(3) Solid Paraplast presents no severe toxicity problem relative to normal care in the handling of any chemical product. Relatively, Paraplast products are not quite as toxic as strong detergents. When re-use of Paraplast is intended, gloves are recommended for handling the solid material to help keep the water contamination at a minimum thus extending the usable working life of the Paraplast.

I. **CATEGORY:** Plastics CODE: 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

e. Color Stability

Within the specified tolerable product temperature range, the color of Paraplast products is unaffected by repeated "heat cycling" or by varying the melting time provided that uniform heating is used.

Excessive overheating, localized "hot spots" heating, or other radical heat application may discolor Paraplast products.

f. Viscosity range

Paraplast #22 has a viscosity similar to water. Other Paraplast products (#33, #44, #55) have a viscosity similar to casting plaster.

g. Solubility

The solubility of Paraplast in water is as follows:

(per 100 parts water)

Cold water at 0°C = approximately 35 to 40 parts per 100 parts water.

Hot water at 100°C = approximately 215 to 230 parts per 100 parts water.

h. Flashpoint

Paraplast products do not have a flashpoint, instead they have a decomposition temperature that is in excess of 1200°F.

i. Melting tank size.

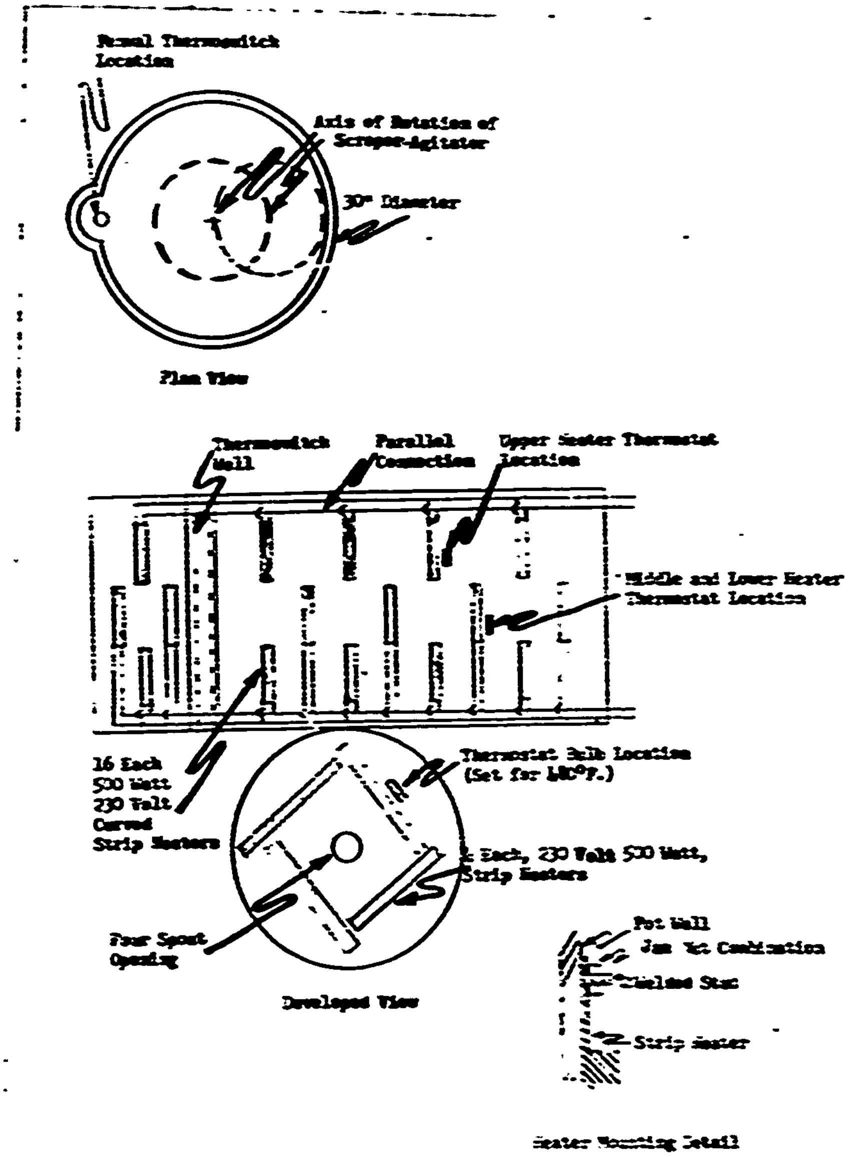
For the average user, a 20 to 30 gallon melting tank is adequate. Use any size melter that fills the demand as no "special" size is required.

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Paraplast Heater Configuration

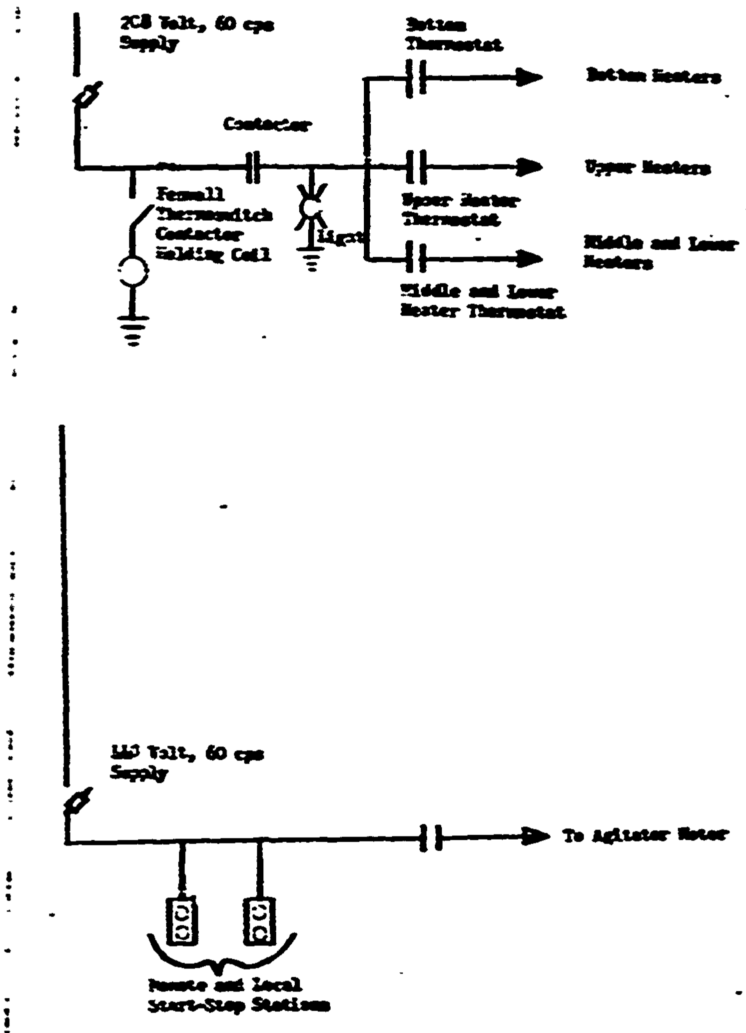
FIGURE 1

I. CATEGORY: Plastics **CODE:** 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Paraplast Heater - Electrical Connections

FIGURE 2

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

j. Melting tank shape

Any shape (square, rectangular, circular, etc.) that does not prevent or impede thorough mixing and agitation of liquid Paraplast products is acceptable.

k. Agitator Requirements

The common propeller type agitator, inserted into the tank from one end is recommended.

l. Temperature control and range

Control within ± 5°F at any temperature up to and including 550°F will allow the use of any Paraplast product (#22, 33, 44 or 55).

m. Discharge valve

A heated (thermostat controlled) discharge valve used to intermittently "tap off" varying amounts of liquid Paraplast is necessary the average size being one inch.

This valve is also used for draining purposes while cleaning or washing out the melting tank. Preferably, this valve should be made of the same type metal that is used for the melting tank.

n. Materials of construction

Cast iron and most grades of steel are very suitable materials for melting and processing equipment for Paraplast. Magnesium or high magnesium content alloys should never be used. Paraplast products are generally considered to be good electrolytes, therefore melting equipment, etc. should consist of a minimum number of different materials.

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

o. Dangers to avoid in melting equipment design

The smallest amount of Paraplast products (i.e., solid, liquid, or granular) that will be used, heated or placed in the melting tank at any time should be determined and the heating control (thermostat or etc.) should be designed and incorporated into the melting tank in such a manner that this minimum amount of Paraplast will be controlled the same as a full tank.

Heating a solid tank full of Paraplast from the bottom alone can develop sufficient pressure to rupture equipment or, more likely, to expel molten Paraplast through the solid surface.

Remelting solid Paraplast should be done in such a manner that the heating surface and heating walls of the melting tank, etc., extend above the level of the solid Paraplast with no erratic or localized heating.

3. Procedure Used to Fabricate Paraplast Mandrels

a. Procedure

(1) Heat the mold to a temperature of approximately 150°F.

(2) Adjust the temperature of liquid Paraplast so that the liquid Paraplast to be used is between 310°F and 315°F.

(3) Pour Paraplast into this mold steadily until the mold is full.

(4) Leave this liquid Paraplast in the mold for approximately 2-1/2 minutes, then pour Paraplast out.

(5) Allow the mold, etc., to cool as required by specific mold configuration.

(6) Break the mold apart and remove the mandrel.

IMPORTANT - After removing the mandrel from the mold, allow sufficient time for the mold to cool back to 150°F in all areas before casting another mandrel - this may take an hour or two.

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3. (continued)

b. Control of Wall Thickness

(1) If it is desired to make a thinner wall mandrel, leave the liquid Paraplast in the mold for a shorter time. If a thicker wall mandrel is desired, do not leave liquid Paraplast in this mold longer than 2-1/2 minutes, as if it is left in this mold longer than 2-1/2 minutes, the thin sections of the mold dissipate heat and the thick sections of the mold absorb and maintain heat. With part of the mold hot, and part of the mold cool, a varied wall thickness in the mandrel will result.

(2) In order to make a thick.. wall mandrel, follow the above procedure (1) through (5) and then leave the mandrel and mold for 1/2 hour or so, enabling the mandrel in the mold to cool down. Then pour Parapl..t right in on top of the mandrel that is in the mold repeating procedure (1) through (6). Using the above technique, good mandrels will result.

4. Cost Analysis of Paraplast No. 33 for Fiberglass Laminating Mandrels

The cost figures shown are average cost of a representative selection of currently fabricated parts. The comparati · results of these average computations can be construed as typical of future part configurations.

The average mandrel fabrication and removal costs per part of the two methods are outlined as follows:

Present Method with Brak-A-Way Plaster	
Mold Cost	$ 1.00
Mandrel Fabrication and Removal	$16.43
TOTAL COST	$17.43

Thirty-two hours flow time for mold fabrication.

Proposed Method "A" Paraplast No. 33 (No Recovery)	
Mold Cost	$ 4.73
Mandrel Fabrication and Removal	$ 6.43
TOTAL COST	$11.16

I. **CATEGORY:** Plastics CODE: 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

4. (continued)

Ninety-four hours flow time for mold fabrication

Proposed Method "B" Paraplast No. 33 (Recovery 97%)

Mold Cost	$4.73
Mandrel Fabrication and Removal	$1.98
Paraplast Cost	$ .13
TOTAL COST	$6.84

Ninety-four hours flow time for mold fabrication.

It is apparent from these computations that an estimated savings of $6.27 per part would accrue from proposed method "A" while savings of $10.59 per part would be realized from proposed method "B".

NOTE: Savings shown do not reflect the reduction in flow time enjoyed as a result of the reduction of mandrel cure time, since flow time is not considered to be a cost factor in this analysis. At higher production rates, the savings in extra sets of molds would be considerable.

I. **CATEGORY:** Plastics　　　　**CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property has not been determined by Boeing-Wichita since such information would be of little or no value from the standpoint of the program as proposed.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics

CODE: 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

C. Electrical

This property has not been determined by Boeing-Wichita since such information would be of little or no value from the standpoint of the program as proposed.

AUTHOR: V. P. Kassions DATE: 9-12-61 **PAGE** 11.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics **CODE:** 6-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PR ERTIES:

D. Chemical

This property has not been determined by Boeing-Wichita since such information would be of little or no value from the standpoint of the program as proposed.

I. **CATEGORY:** Plastics **CODE:** 5-7-1

II. **MATERIAL NAME:** Capabilities and Qualities of Paraplast #33

VI. **RECOMMENDED USES:**

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind. A critical review of our investigative efforts indicated that this material be used as a replacement for break-away plaster in the process of mandrel construction where part characteristics in production economy dictate. A proven procedure for the fabrication of paraplast mandrels is included in this report under A - Mechanical - subheading 3 - Procedure Used to Fabricate Paraplast Mandrels. The recommended procedure for the design criteria of paraplast mandrel parts is included in A - Mechanical - subheading 1 - Handling and Melting Equipment.

VII. **SUPPLIERS AND TRADE NAMES:**

Rezolin Corporation - Paraplast #33

VIII. **REFERENCES:**

A. Boeing-Wichita Manufacturing Research Report 21.8, "Production Evaluation Paraplast #33".

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics

CODE: 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

III. GENERAL DESCRIPTION:

It was the objective of this program to determine the feasibility of utilizing epoxy tubing and associated standardized fittings to produce close tolerance tooling structures.

IV. DEVELOPMENTAL BACKGROUND:

The fabrication of tooling requires much time in the manufacturing process. This program was initiated as a natural step in the continual review of the fabrication of tools. There appeared to be a potential economy available through the utilization of epoxy tubing and the associated standardized fittings. This system was intended to be designed exclusively for use in the Tooling Industry and to simplify fabrication stability for the construction of structural back-ups, for laminated tools, jigs and fixtures.

AUTHOR: W. P. Nassions

DATE: 9-13-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

V. PRINCIPAL PROPERTIES:

A. Mechanical

It was concluded that: (1) epoxy tubing is assembled with ease in the shop, (2) fabrication manhours required may be reduced through the use of epoxy tubing and associated standardized fittings, and (3) the reaction of the material to heat and temperature change imposes definite design limitations as demonstrated in the tables which follow: (Table I through IV give data, Figure I depicts test set-up).

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

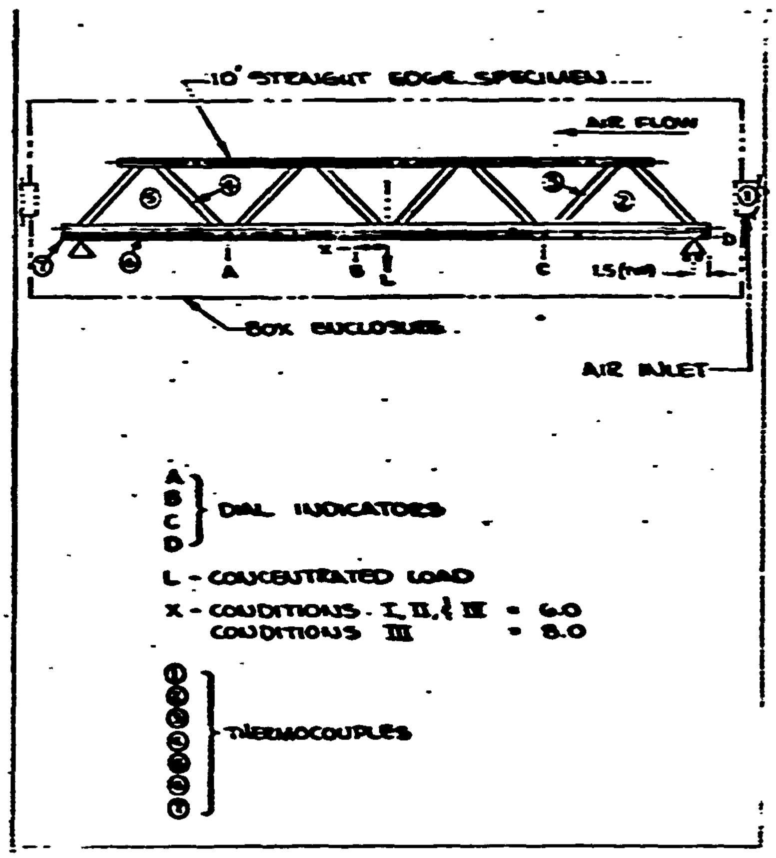


Diagram Test Set-up
10 Ft. Straight Edge Deflection Test

FIGURE I

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing
V. PRINCIPAL PROPERTIES: (Continued)
A. Mechanical (continued)

DEFLECTIONS UNDER VARING CONCENTRATED LOADS AT AMBIENT TEMP. OF 69° F.

SPECIMEN DEFLECTIONS: − 0 +

DIAL INDICATORS ZEROED AT ZERO LOAD

LOAD "L" (LBS)	DEFLECTIONS ~ IN. × 10^{-3}		
	A	B	C
7.3	2.7	3.7	2.7
27.2	9.6	13.7	9.2
47.2	16.4	24.1	16.1
67.2	23.2	34.2	22.7
87.2	30.0	44.5	29.3
107.1	36.9	56.3	36.3
87.2	30.6	45.2	29.9
67.2	23.8	35.0	23.2
47.2	17.2	25.0	16.8
27.2	10.3	14.9	10.0
7.3	3.3	4.4	3.1
0	0.6	0.6	0.3

CONDITION I

10 Ft. Straight Edge Deflection Test

I. CATEGORY: Plastics **CODE:** 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTIONS AT NO LOAD UNDER VARING TEMP.

SPECIMEN DEFLECTIONS − 0 +

ΔT / ΣT (MIN)	TEMPERATURE ~ °F				DEFLECTIONS ~ IN×10⁻⁴		
	3	4	6	7	A	B	C
0	76	77	—	75	6	8	10
15	81	81	—	79	19	23	23
43	89	90	—	·98	70	88	77
57	100	101	—	·99	132	167	132
55 / 0	111	112	—	108	191	243	192
99	122	122	118	119	253	320	247
5 / 5	100	100	108	110	272	347	268
5 / 10	86	85	97	100	252	320	240
5 / 15	79	79	87	89	172	221	172
5 / 20	77	78	83	84	134	170	132
5 / 25	75	76	80	80	99	122	100
5 / 30	75	76	.8	78	76	90	78
5 / 35	74	76	76	77	60	73	62
5 / 40	73	75	75	76	53	63	54
6 / 45	74	76	75	75	45	52	46
9 / 55	74	76	75	75	44	50	46
15 / 70	74	75	75	75	42	47	42
15 / 85	74	76	75	75	42	47	42
[illegible]	76	77	76	76	39	40	37
30 / [illegible]	77	78	73	77	42	47	42

CONDITION II

10 Ft. Straight Edge Deflection Test

TABLE II

I. CATEGORY: Plastics **CODE:** 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTION AT 100# CONCENTRATED LOAD UNDER VARING TEMP.

▷ ZERO CONCENTRATED LOAD

SPECIMEN DEFLECTIONS: − 0 +

ΔT / ΣΔT	TEMPERATURE ~ °F				DEFLECTION ~ IN. × 10^-4		
	3	4	6	7	A	B	C
0	59	62	62	62	977▷	376▷	990▷
14	59	61	61	62	330	940	380
23	70	70	70	70	366	4	438
26	79	79	79	79	445	71	490
37	90	89	89	88	500	137	539
43 / 0	101	100	100	99	580	240	617
55	111	110	109	108	669	359	710
55	122	119	119	118	792	535	841
5 / 5	101	106	108	112	770	—	—
5 / 10	74	83	91	98	618	—	—
5 / 15	63	70	78	83	580	—	—
10 / 25	62	67	69	72	512	—	—
10 / 35	57	60	62	65	490	—	—
10 / 45	58	60	61	60	478	142	528
30 / 75	58	60	61	60	475	150	530
12 / 57	60	61	52	65	110▷	1592▷	1201▷

CONDITION III

10 Ft. Straight Edge Deflection Test

TABLE III

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTIONS AT 93.5# DISTRIBUTED LOAD UNDER VARING TEMP.

SPECIMEN DEFLECTIONS: − O +

ΔT (MIN) / ΣΔT (MIN)	TEMPERATURE ~ °F				DEFLECTION ~ IN × 10⁻⁴		
	3	4	6	7	A	B	C
0	78	78	78	78	7	8	0
30	90	90	89	89	50	52	53
40	103	100	98	99	110	125	110
43	112	109	110	110	186	221	183
112 / 0	124	120	120	120	278	340	270
5 / 5	94	100	103	112	320	398	302
5 / 10	84	88	98	104	253	310	241
5 / 15	81	84	91	94	180	210	171
10 / 25	76	83	87	90	150	170	130
10 / 35	65	72	79	83	110	126	92
10 / 45	63	68	73	77	77	89	66
10 / 55	62	66	70	73	49	52	41
10 / 65	61	65	68	71	32	33	30
32 / 97	61	64	65	67	6	4	12
31 / 123	60	63	63	65	0	997	10
25 / 156	60	62	62	64	0	990	3
29 / 155	60	63	63	64	0	988	2
60 / 265	82	82	79	79	40	37	43

CONDITION IV

10 Ft. Straight Edge Deflection Test

TABLE IV

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

V. PRINCIPAL PROPERTIES:

B. Thermophysical

These properties have not been determined by Boeing-Wichita since there was no existent need under the scope of this program.

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

V. PRINCIPAL PROPERTIES:

C. Electrical

These properties have not been determined by Boeing-Wichita since there was no existent need under the scope of this program.

I. **CATEGORY:** Plastics **CODE:** 6-8-1

II. **MATERIAL NAME:** Epoxy Tubing

VI. **RECOMMENDED USES:**

Epoxy tubing cannot be recommended for use in close tolerance tooling structures because of the dimensional instability of the material.

VII. **SUPPLIERS AND TRADE NAMES:**

Burnham Products, Inc. Ready-Fit Epoxy Tube and Fittings

VIII. **REFERENCES:**

A. Boeing-Wichita Manufacturing Research Report 60.2, "Epoxy Tubing and Fittings for Tooling".

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics

CODE: 6-8-4

II. **MATERIAL NAME:** 3M-471 Plastic Tape

III. **GENERAL DESCRIPTION:**

It was the object of this program to evaluate the subject tape as a stop-off material for potential use in masking prior to anodizing.

IV. **DEVELOPMENTAL BACKGROUND:**

This program was begun in an effort to find a stop-off material for materials and parts, which are to be anodized in specific areas. Present materials used as stop-offs are time consuming in application and removal.

AUTHOR: W. E. Kolins Date: 9-11-61

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics · **CODE:** 6-8-4

II. **MATERIAL NAME:** 3M-471 Plastic Tape

V. **PRINCIPAL PROPERTIES:**

A. **Mechanical**

3M-471 poses handling difficulties and is only suitable for flat surfaces; therefore, the present material, lead-back tape, was considered adequate for the purpose, although further improvements in cutting and forming ability are desirable.

W.H.

I. CATEGORY: Plastics CODE: 6-3-4

II. MATERIAL NAME: 3M-471 Plastic Tape

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics

CODE: 6-8-4

II. **MATERIAL NAME:** 3M-471 Plastic Tape

V. **PRINCIPAL PROPERTIES:**

C. Electrical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

WHK

AUTHOR: W. H. Kolins

Date: 9-11-61

I. **CATEGORY:** Plastics **CODE:** 6-8-4

II. **MATERIAL NAME:** 3M-471 Plastic Tape

V. **PRINCIPAL PROPERTIES:**

D. Chemical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

WHK

AUTHOR: W. H. Kolins Date: 9-11-61

I. **CATEGORY:** Plastics CODE: 6-8-4

II. **MATERIAL NAME:** 3M-471 Plastic Tape

VI. **RECOMMENDED USES:**

This tape cannot be recommended for masking of anything other than flat surfaces.

VII. **SUPPLIERS AND TRADE NAMES:**

3M-471 supplied by Minnesota Mining & Manufacturing Company.

VIII. **REFERENCES:**

Boeing-Wichita, Manufacturing Research Report, 91.1A, "Stop-Off Materials and Procedures for Anodized Parts".

WHK

I. **CATEGORY:** Plastics   **CODE:** 6-8-6

II. **MATERIAL NAME:** Epoxy-Mat Mold Dies

III. **GENERAL DESCRIPTION:**

It was the object of this project to evaluate mat mold die materials, Furane 10Q and 10P, filled with special aluminum fibers.

IV. **DEVELOPMENTAL BACKGROUND:**

A large proportion of the cost of a fabricating Kirksite mat mold dies lies in the hours required to hand finish the cavity. In addition, porosity of Kirksite is such that a machine finish which will produce high quality surface of the finished plastic part is quite difficult to obtain. Use of plastics as a mat mold die material is not new. It has been recognized that materials other than Kirksite could produce a superior surface finish. Plastic parts molded in plastic mat mold dies have improved surface finishes, parting problems are reduced and the die construction costs are decreased. For this reason, interest is always shown toward improvements in plastics which may be used for this purpose.

I. **CATEGORY:** Plastics

CODE: 6-8-6

II. **MATERIAL NAME:** Epoxy Mat Mold Dies

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Upon completion of the tool it was found that heat transfer was poor and that considerable warpage occurred. The die was heated from the base by a heated platen on the press. Heat transfer was so poor that the platen temperatures had to be elevated to 400°F. before the die cavity reached 210°F. Specific requirements are 225 - 250°F for the curing of the resins. However, sample parts were cured at the lower temperatures. Surface finish for the cured parts proved to be better than that obtained with conventional Kirksite dies. Consideration was given to finding ways to improve the heat transfer characteristics of the existing tool but it was decided that any rework attempt would not be economical. Furane Plastics, Inc., was asked to provide data to support their claim that a higher aluminum ratio would provide heat transfer desired. This information was never furnished and the project was closed.

I. **CATEGORY:** Plastics

CODE: 6-8-6

II. **MATERIAL NAME:** Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property was not determined since there was no existent need under the program for its determination.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

C. Electrical

This property was not determined since there was no existent need under the program for its determination.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

D. Chemical

This property was not determined since there was no existent need under the program for its determination.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Plastics

CODE: 6-8-6

II. **MATERIAL NAME:** Epoxy Mat Mold Dies

VI. **RECOMMENDED USES:**

As a result of the investigative efforts expended, it was recommended that unless new developments occur which improved this procedure, that it not be considered or recommended for production.

VII. **SUPPLIERS & TRADE NAMES:**

Furane Plastics, Inc.	Curing Resins 10Q and 10P
Reynolds Aluminum Co.	#200 Aluminum Powder

VIII. **REFERENCES:**

Boeing-Wichita, Manufacturing Research Report 60.6, "Plastic Mat Mold Die Fabricated from Furane 10Q High Temperature Gel-Coat and 10P High Temperature Bonding Resins".

AUTHOR: V. P. Messions   Date: 9-11-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Epoxy-Polyamide

III. GENERAL DESCRIPTION:

The objective of this job was to evaluate the properties of a blend consisting of Epon 828, Epon 812, and Versamid 115-125.

IV: DEVELOPMENTAL BACKGROUND:

At the time the evaluation of the epoxy-polyamide system was originated, bonding of fiberglass reinforcing doublers to fuel tank fiberglass backing boards was accomplished using a polyester resin for the adhesive. Poor quality bonds coupled with accelerated production rates required a change to a more suitable adhesive.

Preliminary testing indicated that an epoxy-polyamide system would produce good quality, high strength bonds, and that the adhesive could be cured in a relatively short time.

AUTHOR: Marlyn Harp 16 August 1961

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Fuel Resistance

a. Lap shear specimens with one-half inch overlaps were prepared by bonding polyester laminates (BMS 8-9) to themselves with the adhesive. Bonds were cured for 15 minutes at 250°F under 10-15 psi pressure.

b. Specimens were immersed for seven days at room temperature in MIL-H-3136 Type III and MIL-F-5624 type JP-4 fuels.

c. The specimens were tested in shear at the end of the soak period and, in each instance, the fiberglass laminate failed at loads below those required to fail the bond.

2. Water Resistance

a. Other specimens prepared at the same time as A.1. above were immersed in water for seven days at room temperature, and tested in shear. The bonds on these specimens failed at loads on the order of 1000 psi. Visual examination indicated the adhesive had been softened by exposure to water.

3. Environmental Resistance

Many tests involving different materials have been bonded with the epoxy-polyamide described herein, after the orgination of the initial work described above. Salt spray cabinet, humidity cabinet and weather cabinet tests have been conducted where the adhesive was used over solvent cleaned surfaces, chemically cleaned surfaces and over different primers. These tests were run independently of each other at different times over a long period of time. Therefore, comparative data would be of little value. A general summary is therefore given below:

a. Generally it has been found in nearly all tests that the condition of the metal surface influences the resistance of the adhesive to different environments. Surfaces which have been hand cleaned by solvent degreasing only, nearly always fall apart in handling after exposure to salt spray for 30 days. Humidity cabinet tests and accelerated weather test data usually are not as severe but test values are lowered.

I. CATEGORY: Liquid and Semi-Solid High Polymers   CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (Continued)

b. Panels which have been cleaned by a sodium dichromate sulphuric acid solution show little if any differece in bond strength after environmental aging.

c. Bonds where the adhesive is used over a primer are limited only by the strength of the primer. Bond failures therefore are the result of the primer failing to the metal surface.

d. It has been found that failures of the solvent cleaned bonds are due to interfacial penetration at the bond interface. Apparently no degradation of the material occurs.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Epoxy-Polyamide

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

The epoxy-polyamide combination used at Boeing-Wichita and covered by this report is thermoplastic. The cured material softens between 160°F and 180°F.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Epoxy-Polyamide

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Epoxy-Polyamide

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

It has been determined that a blend consisting of equal proportions of epoxy and polyamide is useful in many non-structural applications where a high strength (in shear), flexible adhesive is required. Its ease of application, fast cure rate and compatibility with many different materials is beneficial.

Careful consideration to all problems related to a specific application is necessary however, because of its marginal weather resistance and poor heat resistance. The cured material should not be used in exterior applications unless the metal surfaces are either chemically etched, or primed prior to adhesive application. In the latter instance, it has been found that EC-776R (a nitrile rubber base material) used as a primer improves the weather resistance of an epoxy-polyamide bond.

Since the epoxy-polyamide blend discussed in this report is thermoplastic, its use should be limited to service temperatures which do not exceed 140°F.

VII. SUPPLIERS AND TRADE NAMES:

A. The supplier designations and location are as follows:

Epon 828 and Epon 812 -	Shell Chemical Corporation Pittsburg, California
Versamid 115 and Versamid 125	General Mills Incorporated Kankakee, Illinois

B. Availability

The individual materials are packaged in one pint, one quart, and one gallon containers.

C. Costs

Epon 828	\$1.58 per pound
Epon 812	1.87 " "
Versamid 115	0.85 " "
Versamid 125	1.10 " "

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Epoxy-Polyamide

VIII. **REFERENCES:**

(1) Wichita Materials and Process Unit Report AP-2-127, Evaluation of an Epoxy-Polyamide Resin Combination.

(2) Wichita Materials and Process Unit Report AP-2-13, Salt Spray Tests on Plastic to Aluminum Bonds.

(3) Wichita Materials and Process Unit Report AP-2-91, BMS 10-11 As An Adhesive Primer.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Silicone Q-3-0121

III. **GENERAL DESCRIPTION:**

The objective of this program was to conduct preliminary tests on a new one-part air curing silicone adhesive.

IV. **DEVELOPMENTAL BACKGROUND:**

Dow Corning Q-3-0121 is a new development product which appears to offer many advantages for repair or production bonding of non-structural silicone rubber parts.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Rubber to Rubber Bonds

Rubber-to-rubber peel test specimens of the configuration shown in Figure 1 were bonded in accordance with MIL-A-25457A. Specimens were assembled after an open air dry time of 15-30 minutes, and, after no open dry time. The bonds were cured for six hours, 24 hours, and 168 hours at room temperature.

Failures on those specimens assembled immediately were generally in the rubber. Photograph EMA-12201 presents a typical failure. Those specimens which were assembled after an open air dry time resulted in failures at loads on the order of nine pounds per inch width.

On the basis of the above failures and because of the limited amount of adhesive available for test, it was decided that further testing on the type specimens depicted on Figure 1 should be discontinued. Therefore, the test specimen configuration was changed to conform to the requirements of MIL-A-25457A (Douglas T-Peel Method). Data on rubber-to-rubber bonds in Table I were obtained on these type specimens.

It will be noted from Table I, that those specimens assembled while the adhesive was wet resulted in cohesive failures while those specimens which were assembled after an open air dry time (tacky) were adhesive failures.

2. Rubber to Metal Bonds

Peel test specimens were prepared by bonding strips of MIL-R-5847 Grade 50 rubber to .064 clad panels per MIL-A-25457A. The bonds were assembled and cured in the same manner as those in Section A.1. above.

Failures on all specimens were generally cohesive failures with some isolated adhesive failures. Test values are shown on Table I.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

A. Mechanical

SPECIMEN CONFIGURATION

RUBBER TO RUBBER

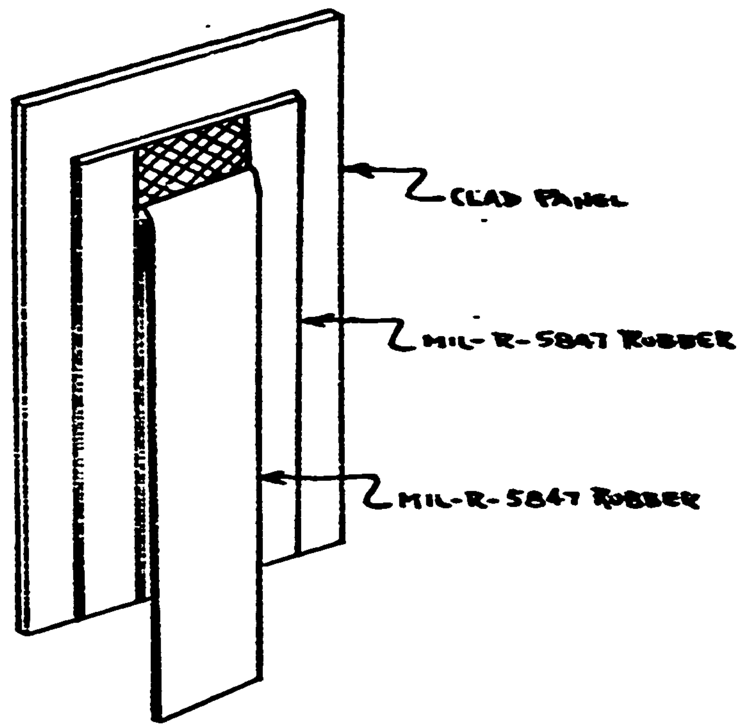


FIGURE 1

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

C. Electrical Properties

METHOD OF ASSEMBLY	CURED 6 HRS PEEL #/IN.	FAILURE	CURED 24 HRS PEEL #/IN.	FAILURE	CURED 7 DAYS PEEL #/IN.	FAILURE
TACKY-	13.0	COHESIVE	12.0	COHESIVE	15.0	COHESIVE
15-30 MINUTE	11.0	"	12.0	"	16.5	"
OPEN TIME	13.0	"	12.0	"	15.5	"
	8.0	ADHESIVE	12.0	"	15.5	"
	8.0	ADHESIVE	11.0	"	15.5	"
WET-	11.0	30-40% Coh	16.0	COHESIVE	22.0	COHESIVE
ASSEMBLED	16.0	COHESIVE	17.0	"	20.0	"
IMMEDIATELY	17.0	"	19.0	"	22.5	"
	17.0	"	19.0	"	22.0	"
	17.0	"	18.0	"	22.0	"

Rubber to Metal

METHOD OF ASSEMBLY	CURED 6 HRS PEEL #/IN.	FAILURE	CURED 24 HRS PEEL #/IN.	FAILURE	CURED 7 DAYS PEEL #/IN.	FAILURE
TACKY-	5.0	ADHESIVE	4.0	ADHESIVE	5.5	ADHESIVE
15-30 MINUTE	3.0	"	4.0	"	5.0	"
OPEN TIME	3.0	"	4.0	"	6.25	"
	3.0	"	4.0	"	4.5	"
	4.0	"	4.0	"	4.5	"
WET-	13.0	COHESIVE	12.5	90% Coh	15.0	COHESIVE
ASSEMBLED	12.0	"	13.5	COHESIVE	16.5	RUBBER BRAKE
IMMEDIATELY	12.0	"	13.0	"	15.5	COHESIVE
	13.0	"	12.5	"	15.5	"
	13.0	"	15.0	"	15.5	"

Rubber to Rubber

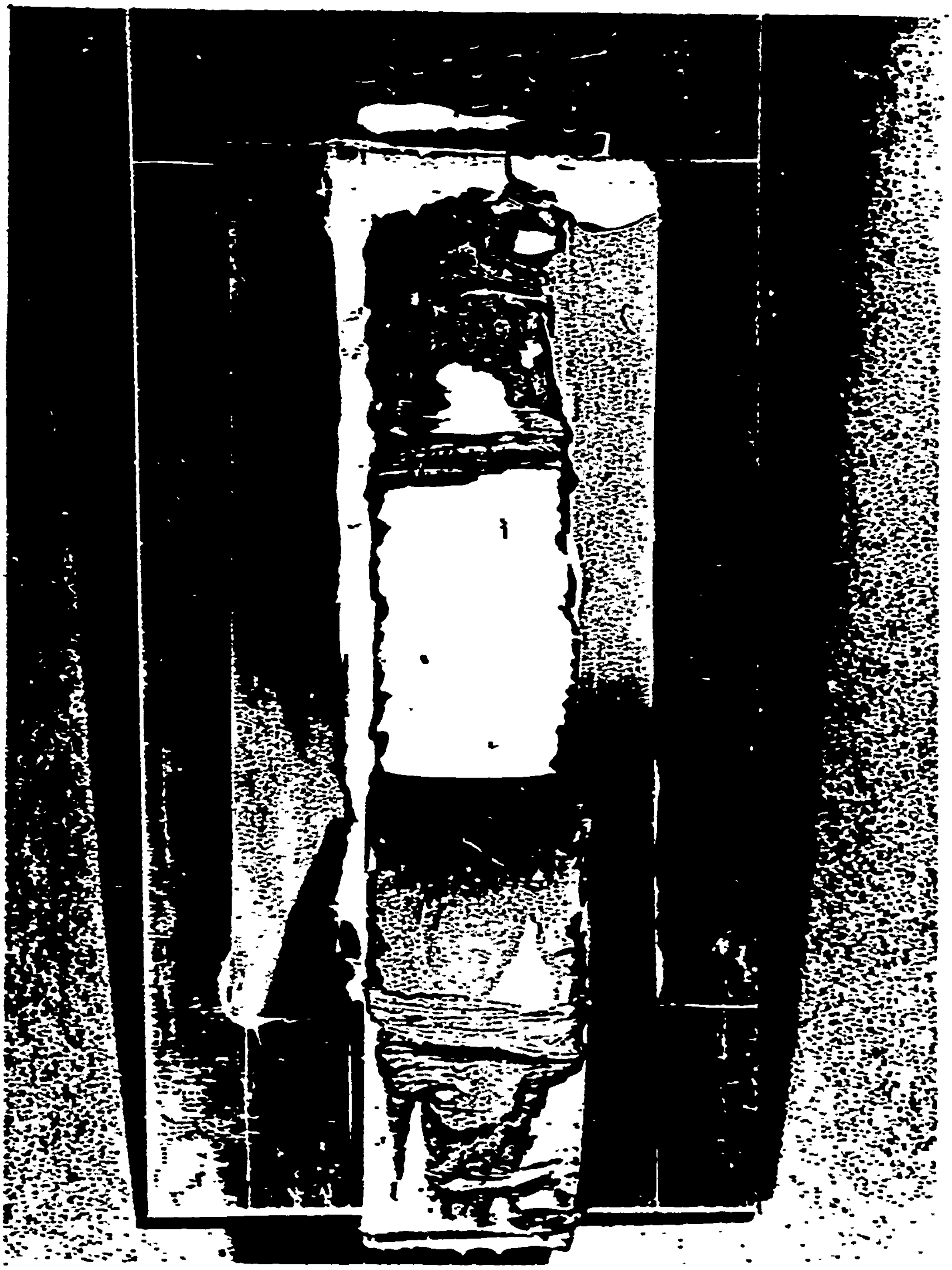
TABLE I

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Silicone Q-3-0121



AUTHOR: Marlyn Harp

BWA-12201
15 August 1961

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Silicone Q-3-0121

V. **PRINCIPAL PROPERTIES:**

3. Thermophysical

Rubber to clad peel test specimens as prepared in Section A.2, but cured for 24 hours, were placed in an oven and further aged for 24 hours at 212°F. A two pound weight was suspended from the unbonded end of the rubber. Inspection for separation or other signs of degradation was conducted after 24 hours. No failure was evident, so the temperature was raised to 400°F for 24 hours, and, re-inspected. No degradation was noted at this temperature, so the temperature was raised to 500°F for 24 hours. Upon inspection it was noted that the bond could be separated easily by hand. There was also evidence that the material tends to revert at this temperature.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Silicone Q-3-0121

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information not available due to lack of need for Boeing-Wichita investigating this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita investigating this property.

AUTHOR: Marlyn Harp 15 August 1961

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

The bond strength of Q-3-0121 is superior to any silicone adhesive (either RTV or heat vulcanizing types) tested to date. The elimination of a primer, the elimination of separate curing agents and the simplicity of application makes the adhesive extremely useful for non-structural silicone rubber bonding applications, both in the field and in production shops.

Q-3-0121 should be limited to applications where the service temperatures do not exceed 400°F. Also for best bond strengths, bond closure should be effected as soon as possible after the adhesive has been applied to the faying surfaces.

VII. SUPPLIERS AND TRADE NAMES:

A. The vendor designation and location is as follows:

Dow Corning Q-3-0121 Silicone Adhesive
Dow Chemical Corporation
Midland, Michigan

B. Availability

Q-3-0121 is packaged in two ounce and eight ounce collapsible metal tubes, or in polyethylene sealant cartridges.

C. Costs

The price of Dow Corning Q-3-0121 is approximately \$2.50 for a two ounce package.

VIII. REFERENCES:

(1) Wichita Materials and Process Unit Report AP-2-75, Testing of Dow Corning Q-3-0121 Silicone Adhesive.

(2) BAC Process Specification 5010, Application of Adhesives.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

III. GENERAL DESCRIPTION:

The objective of this program was to determine the best cure conditions, effect of bond line thickness, and environmental resistance of Shell Epon 928.

IV. DEVELOPMENTAL BACKGROUND:

Epon 928 is a thixotropic, two-part, non-metallic adhesive material. Interest in the material was generated when a project developed which required the use of a non-metal filled material for plastic-to-plastic structural bonding.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

A. **Mechanical**

1. Determination of Cure Conditions

a. Lap shear panels of an epoxy laminate (DER332) were bonded together to form one-half inch overlap joints.

b. The cure temperature, cure time, and order of bonding was in accordance with the experimental plan below:

Cure Temp. °F	200				250				300				350			
Cure Time, Min.	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
Bonding Order	(14)	(12)	(16)	(10)	(9)	(4)	(8)	(5)	(2)	(7)	(1)	(11)	(6)	(3)	(13)	(15)

NOTE: The bonding order was a random selection. The plan was repeated three times.

c. The results of the cure cycle determination are summerized on Table I. Figure 1 illustrates graphically the effect of each factor on bond strength.

2. Effect of Bondline Thickness

a. Lap bond panels of .064 clad were bonded together to form one-half inch overlap joints. The metal details were cleaned per BAC 5765, Method 2.

b. Bond line thicknesses were varied as shown below:

Bond Thickness - Inches	.005	.010	.025	.030

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

CURE TEMP. °F.	200				250				300				350			
CURE TIME-MINUTES	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
	1805	1578	1555	[illegible]	1910	1993	1932	2095	1550	1567	1863	1850	1935	[illegible]	1732	[illegible]
	1887	2286	2008	[illegible]	1583	1156	2017	1757	[illegible]	1588	1964	[illegible]	1583	1557	2029	[illegible]
	1546	2027	1915	1596	2095	1893	1939	1857	1935	1866	1913	1570	1966	1867	2015	1555
AVERAGE	1882	2095	1925	1932	1539	1927	1902	1851	[illegible]	1557	1850	[illegible]	[illegible]	1863	1933	1583

CURE TIME-

15 MINUTES AVERAGE: 1895

30 MINUTES AVERAGE: 1932

45 MINUTES AVERAGE: 1925

60 MINUTES AVERAGE: 1906

CURE TEMPERATURE-

200°F AVERAGE: 1935

250°F AVERAGE 1931

300°F AVERAGE: 1885

350°F AVERAGE: 1987

Different Cure Conditions Lap Shear - PSI

TABLE I

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

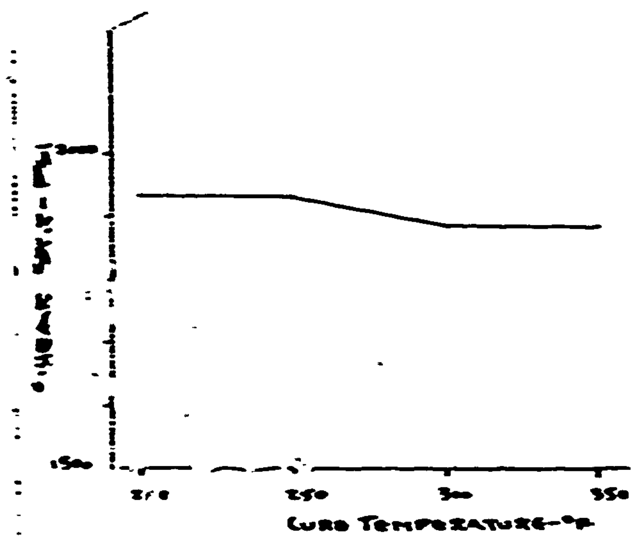
I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

EFFECT OF CURE TEMPERATURE



EFFECT OF CURE TIME

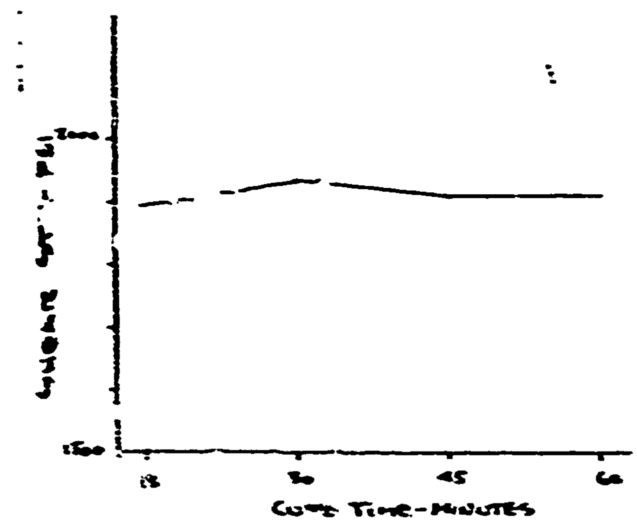


FIGURE 1

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

c. The effect of bondline thickness is shown on Figure 2 and Table II through Table V.

3. Environmental Tests

a. Lap bond panels of the same description as in A.1. were prepared except the bonds were cured for 30 minutes at 250°F. Five bonded assemblies were fabricated for each of the following environments:

30 day Humidity Cabinet Test per Reference (2), Method 6201.
30 day Salt Spray Test per Reference (2), Method 6061.
30 day Weather Cabinet Test per Reference (2), Method 6152.
30 day immersion in toluene at room temperature.

b. Two specimens from each panel were retained for control aging at room temperature.

c. The environmental test data are summarized in Table VI.

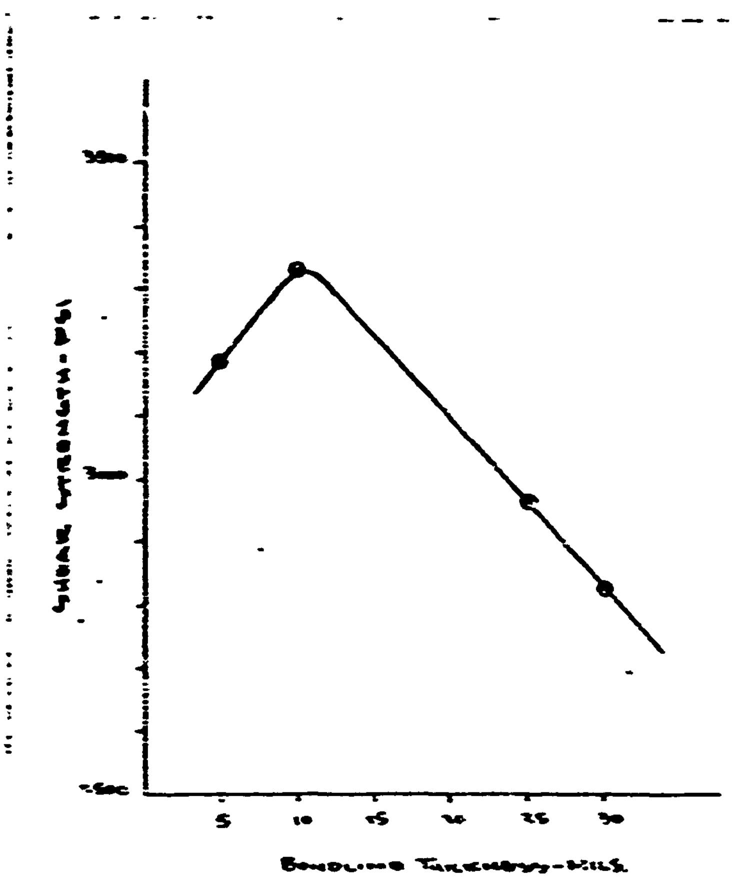
d. All failures were in the resin surface layer of the laminate.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Effect of Bondline Thickness on Bond Strength

FIGURE 2

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.064 CLAD AL.	250°F	30 MIN	3-5 P.S.I.

COMMENTS: .005 BOND LINE THICKNESS

MICROLAM PULL RATE: 600-700 LB PER MIN

PLATEN ✓ PULL DATE: DEH 3-21-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.005 1-1	.007	.52	1.003	1310	2519	
2	.007	|	.995	1395	2698	
3	.005	|	1.003	1325	2548	
4	.005	|	1.001	1600	3077	
5	.005	.52	1.004	1550	2980	2764 AVERAGE
.005 2-1	.006	.50	1.002	1665	3330	
2	.006	|	.995	1785	3591	
3	.005	.50	1.003	1775	3550	
4	.006	|	1.001	1815	3630	
5	.006	.50	1.004	1470	2940	3408 AVERAGE
.005 3-1	.006	.50	1.002	1585	3170	
2	.005	.51	.995	1620	3195	
3	.005	.51	1.002	1855	3598	
4	.005	.51	1.002	1800	3529	
5	.007	.52	1.004	1755	3375	3373 AVERAGE

Effect of Bondline Thickness 5 MIL Thick Bond

TABLE II

AUTHOR: Marlyn Harp 28 August 1961

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.064 CLAD AL.	250 °F	30 MIN	3-5 P.S.I.

COMMENTS: .010 BOND LINE THICKNESS

AUTOCLAVE

PLATEN ✓

PULL RATE: 600-700 LB/min.

PULL DATE: DEH 3-21-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.010 1-1	.009	.51	1.002	1765	3460	
2	.011		.995	1635	3323	
3	.010		1.002	1775	3452	
4	.010		1.003	1650	3235	3375 AVERAGE
5	.011	.51	1.003	—		[illegible] not recorded
.010 2 1	.011	.52	1.002	1735	3336	
2	.010	.52	.995	1795	3472	
3	.010	.52	1.002	1805	3471	
4	.009	.52	1.001	1870	3596	
5	.010	.51	1.004	1790	3510	3577 AVERAGE
.010 3-1	.010	.51	1.002	1575	3059	
2	.010	.51	.995	1500	2955	
3	.010	.52	1.002	1675	3221	
4	.010	.52	1.001	1640	3154	
5	.009	.52	1.004	1620	3231	3130 AVERAGE

Effect of Bondline Thickness 10 MIL Thick Bond

TABLE III

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR. 6-22	.064 CLAD AL.	250°F	30 MIN.	3-5 P.S.I.

COMMENTS: .025 BONDLINE THICKNESS

AUTOCLAVE

PLATEN ✓

PULL RATE: 600-700 LB/min

PULL DATE: DEN 3-22-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.025 1-1	.024	.51	1.002	1525	2990	
2	.025	|	.995	1485	2929	
3	.025	|	1.003	1370	2686	
4	.025	|	1.002	1265	2480	
5	.025	.51	1.004	1520	2980	2813 AVERAGE
.025 2-1	.024	.51	1.004	1615	3167	
2	.023	|	1.001	1645	3225	
3	.025	|	1.003	1560	3059	
4	.025	|	.995	1470	2899	
5	.025	.51	1.002	1440	2823	3035 AVERAGE
.025 3-1	.024	.52	1.004	1625	3125	
2	.023	.52	1.001	1580	3033	
3	.023	.52	1.002	1510	2904	
4	.024	.52	.995	1530	2959	
5	.025	.51	1.003	1530	2996	3004 AVERAGE

Effect of Bondline Thickness 25 MIL Thick Bond

TABLE IV

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.063 CLAD ALUM	250°F	30 MIN.	3-5 P.S.I.

COMMENTS: .030 BOND LINE THICKNESS

AUTOCLAVE

PLATEN ✓

PULL RATE: 600-700 LB/MIN

PULL DATE: Comp. 3-21-61 DLH

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.030 1-①	.031	.52	1.004	1,450	2788	-
②	.030	|	1.003	1,395	2683	
③	.030	|	1.002	1,355	2606	
④	.030	|	.996	1,525	2950	
⑤	.031	.52	1.003	1,480	2846	2775 AVERAGE
.030 2 ①	.031	.51	1.005	1,555	3049	
②	.031	|	1.002	1,355	2651	
③	.031	|	1.003	1,495	2931	
④	.032	|	.995	1,235	2435	
⑤	.031	.51	1.002	1,395	2735	2761 AVERAGE
.030 3 ①	.029	.52	1.005	1,595	3067	
②	.029	|	1.002	1,470	2527	
③	.030	|	1.003	1,490	2865	
④	.031	|	.996	1,530	2959	
⑤	.031	.52	1.002	1,545	2971	2935 AVERAGE

Effect of Bondline Thickness 30 MIL Thick Bond

TABLE V

I. CATEGORY: Liquid and Semi Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TOLUENE		SALT SPRAY		HUMIDITY		WEATHER-O-METER		
CONTROL	TEST	CONTROL	TEST	CONTROL	TEST	CONTROL	TEST	
2398	2505	2251	1923	2376	2167	2288	1761	
2455	2397	2206	1809	2355	1956	2050	1752	
2002	2366	2052	2155	1887	[illegible]	2132	[illegible]	
1557	1563	2085	2027	1927	2034	2154	1719	
2036	1959	2046	1514	2302	2070	2366	1665	
1944	1927	2026	1861	2356	2017	2150	1582	
2056	1844	2022	1760	2098	2054	2312	1576	
2254	2095	1990	[illegible]	2020	1956	1961	1715	
2156	2066	2010	1769	2252	1956	1557	1706	
2515	2256	2138	1864	2134	2157	1961	1521	
	2090		1826		2263		1522	
	2165		1995		2332		1958	
	2434		2100		1992		1935	
	2335		2216		1119		2022	
	2209		2591		1925		1715	
2181	2175	2059	1976	2161	2069	2157	1801	AVERAGE

Environmental Tests

TABLE VI

I. **CATEGORY:** Liquid and Semi Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

Information not available due to lack of need for Boeing Wichita's investigating this property

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Shell Epon 928

VI. **RECOMMENDED USES:**

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

The tests in this report demonstrate the versatility of Epon 928 in curing. The material will cure at room temperature or it can be force cured at any time-temperature interval between 200-350°F for 15-60 minutes. This flexibility in curing allows the designer to apply the adhesive at nearly any production step in the fabrication of a plastic part. It can be applied and cured at the bench on a detail part, or applied to the major assembly and cured at temperatures which are required to cure other parts of the assembly.

Some sacrifice in bond strength may be expected where bondline thicknesses exceed 10 mils. However, the strengths obtained on the thicker bondlines indicates the material would be useful in gap filling applications where a high strength bond is also required.

VII. **SUPPLIERS AND TRADE NAMES:**

A. The Supplier designation and location is as follows:

Epon 928 - Shell Chemical Corporation, Pittsburg, California.

B. Availability:

Epon 928 is packaged in pint, quart, and gallon containers.

C. Costs:

The price of Epon 928 is approximately $9.00 per quart.

VIII. **REFERENCES:**

(1) Wichita Materials and Process Unit Report AP-1-35, Testing Shell Epon 928.

(2) Federal Test Method Standard No. 141.

(3) BAC 5765, Cleaning and Deoxidizing Aluminum Alloys.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

III. GENERAL DESCRIPTION:

The objective of this program was to determine the effect of certain variables on cured adhesive bonds with HT-424 Adhesive and Aluminum.

IV. DEVELOPMENTAL BACKGROUND:

HT-424 Adhesive has been approved by Boeing for use as a heat resistant structural bonding material for aluminum (metal-to-metal and honeycomb sandwich) on flight vehicles. The adhesive is qualified under MIL-A-5090.

Boeing specifications governing the use of this adhesive specify the minimum requirements in BMS 5-17 and BAC 5450. There are many conditions specified by design that cannot reasonably be covered in general usage specifications. Since this is a heat resistant adhesive, testing at elevated temperatures is also required and complicates the evaluation of properties. It was thought to be worthwhile to investigate variables in test methods and to determine properties of the material (on which data are not readily available) for use in advising design and manufacturing shops.

AUTHOR: K. Methvin **DATE:** 8/24/61

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

1. The effect of heat-up time (to cure temperature) on peel and 500°F lap shear strength is shown in Figures 1 and 2. The single (1/2 inch overlap) shear specimens were made from 2024-T3 clad aluminum 0.063 inch thick. The peel specimens were 5052 alloy aluminum core (perforated), 3/16 inch cell size x .002 inch foil x 5/8 inch thick with 2024-T3 clad aluminum skins, .020 gage bonded together with HT-424. Peel testing was done with a "climber" peel tester per MIL-A-25463.

   Varying the heat-up time between 20 and 60 minutes to cure temperature had no appreciable effect on peel strength. Lap shear strength appeared to be lower when the assembly was heated up between 20 and 40 minutes to cure temperature compared to a slower heat time of 40 to 60 minutes.

2. The effect of room temperature exposure of uncured HT-424 on subsequent bond strengths is shown in Figure 3. Bond materials and test methods were the same as specified in (1) above. Cure conditions were also the same - 325 to 350°F for 45 minutes.

3. The effect of glue line thickness on 500°F lap shear strength of HT-424 adhesive in clad aluminum joints is shown in Figure 4. Apparently, there is a considerable difference in strength due to bond thickness depending upon the degree of porosity of the glue line. No effort was made in the Boeing bonded panels to restrain the adhesive in the joint, and thereby minimize porosity. The Bloomingdale bonded panels were bonded in such a manner as to restrain the adhesive in the joint, thereby providing a more dense glue line. It is thought that a thick, dense glue line would be more representative of actual assemblies.

4. Figure 5 shows the relationship of temperature and pressure on uncured HT-424 adhesive (and others) in a closed container. The test data are designed to give information on the amount of bonding pressure required to bond a 5/8 inch thick non-perforated sandwich. These data do not take into account pressure leak-off through the cloth carrier during cure. Therefore, the data represents maximum pressure that could ever be experienced in curing such as assembly.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

A. Mechanical (continued)

5. Table 1 and Figures 6 through 10 give the effects of variables in the 500°F lap shear test on shear strength of HT-424 in clad aluminum bonds. All panels were bonded at 325°F for 45 minutes on the same day from the same batch of HT-424 adhesive. This particular batch happened to be about 150 psi lower in shear strength than the average material received over the past two years.

The data indicates that variations in heat-up time between 3 and 20 minutes to 500°F do not significantly affect 500°F lap shear strength. There is a significant difference (approximately 60 psi) between bonds aged 60 minutes at 500°F and those unaged (but tested) at 500°F. There is a significant difference in 500°F shear values with a 25°F change in temperature from 500°F. The test was not adequately controlled to determine conclusively whether there was a significant difference between bonds tested in an air circulating oven and those tested in a (radiant heat) Marshall furnace. However, it is believed that the difference is not significant.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

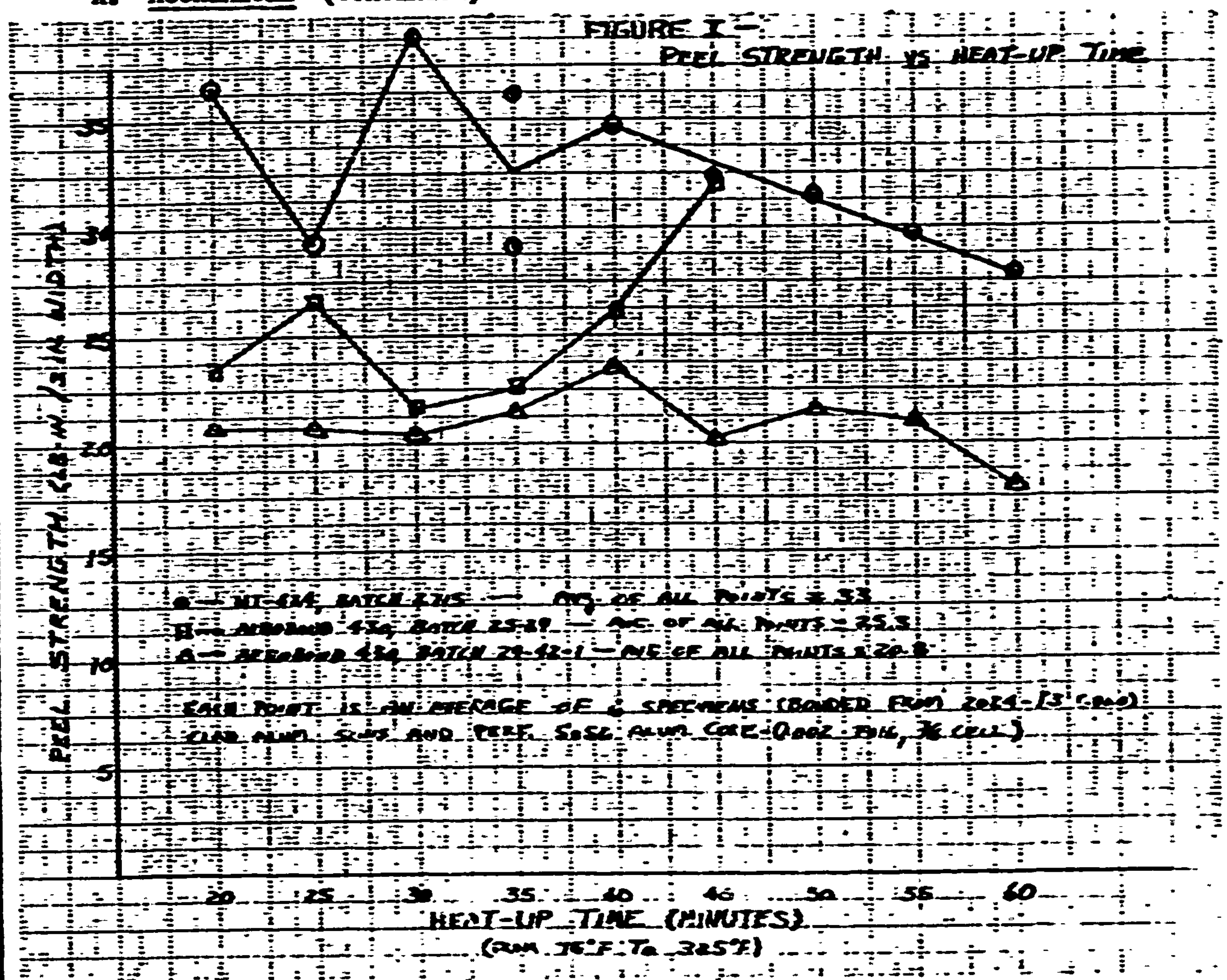
AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



AUTHOR: K. Methvin DATE: 8-24-61 PAGE 4

BOEING AIRPLANE COMPANY
WICHITA DIVISION

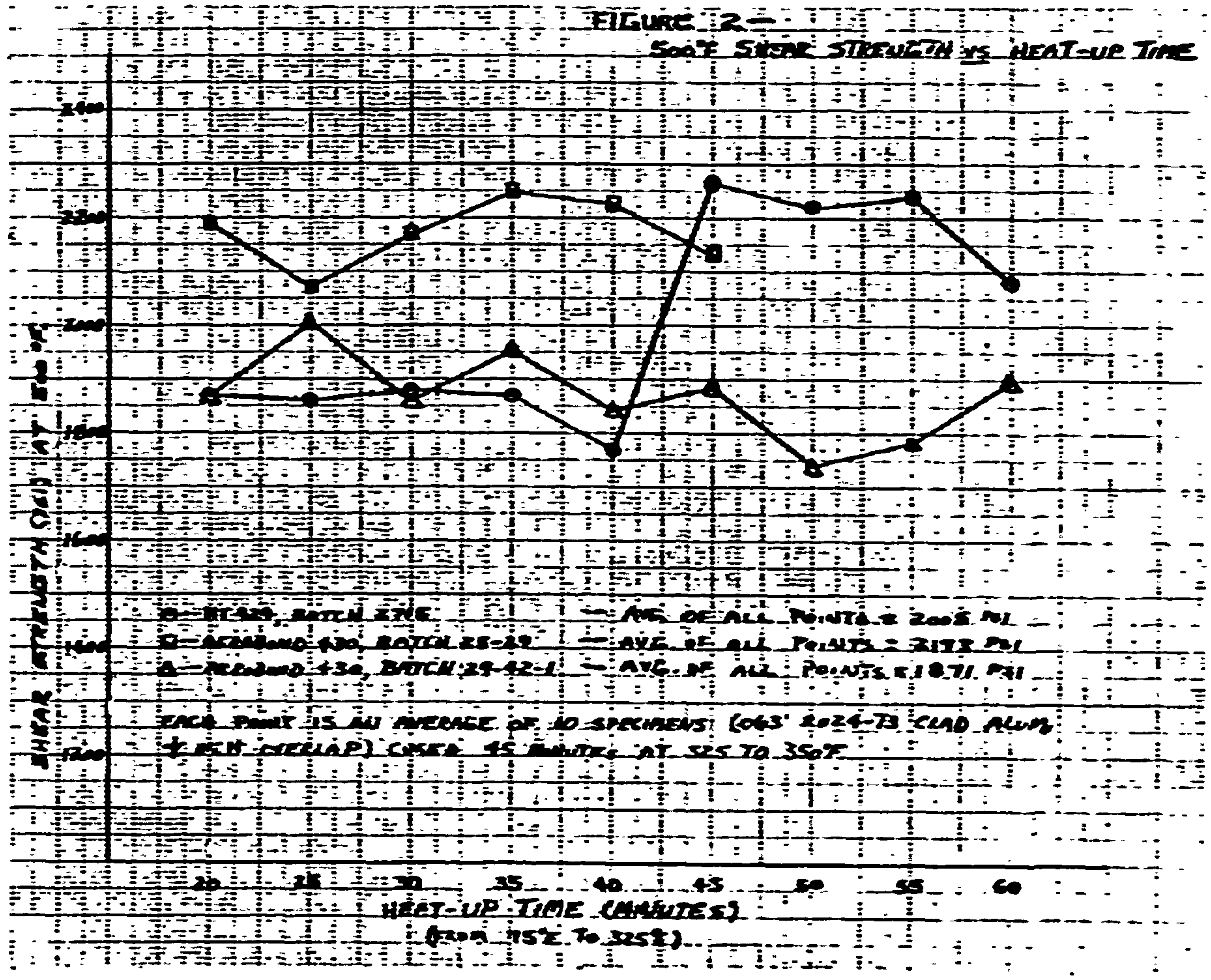
AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



AUTHOR: K. Methvin DATE: 8-24-61 PAGE 5

MATERIALS & PROCESS UNIT

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BOEING AIRPLANE COMPANY
WICHITA DIVISION

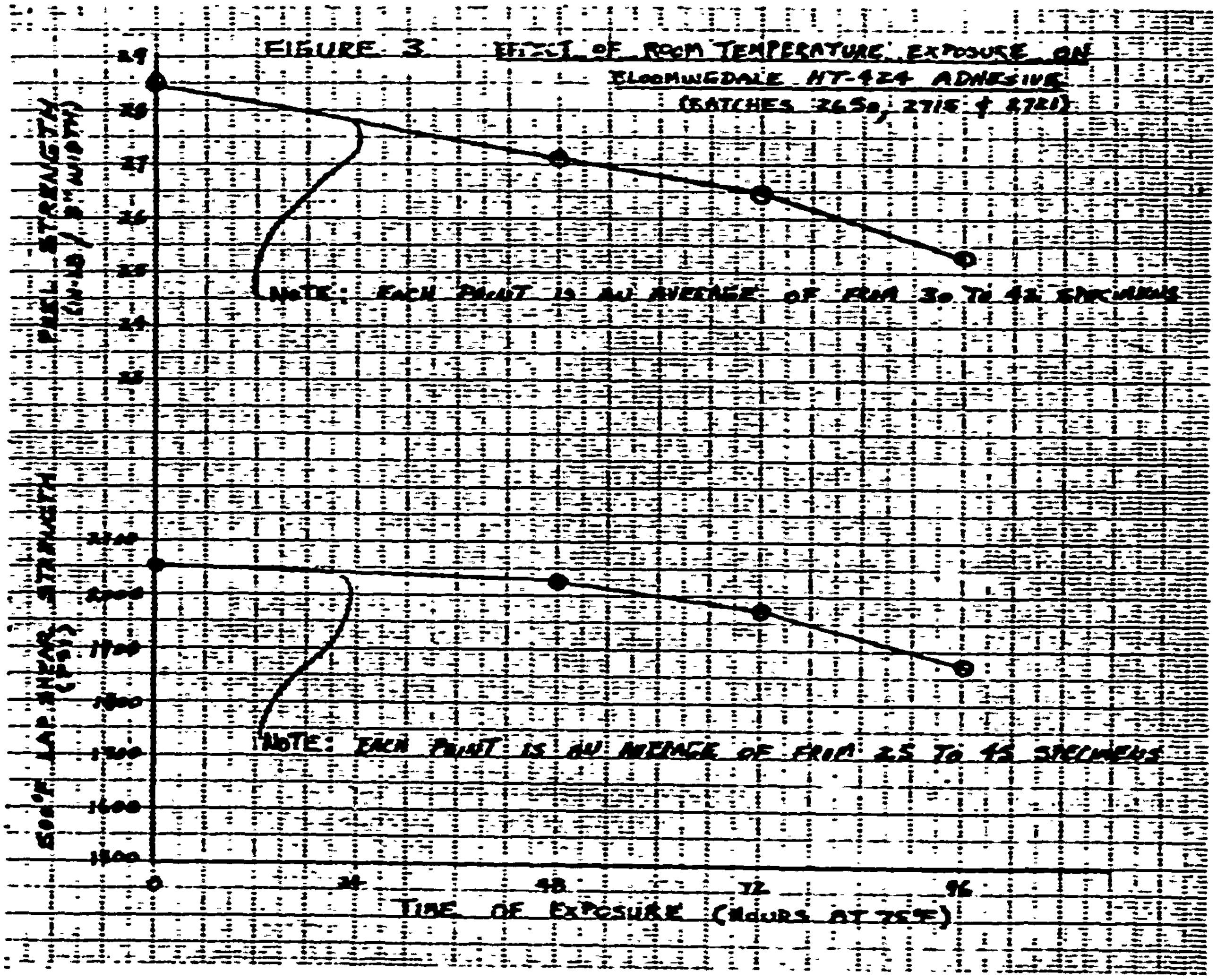
AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)



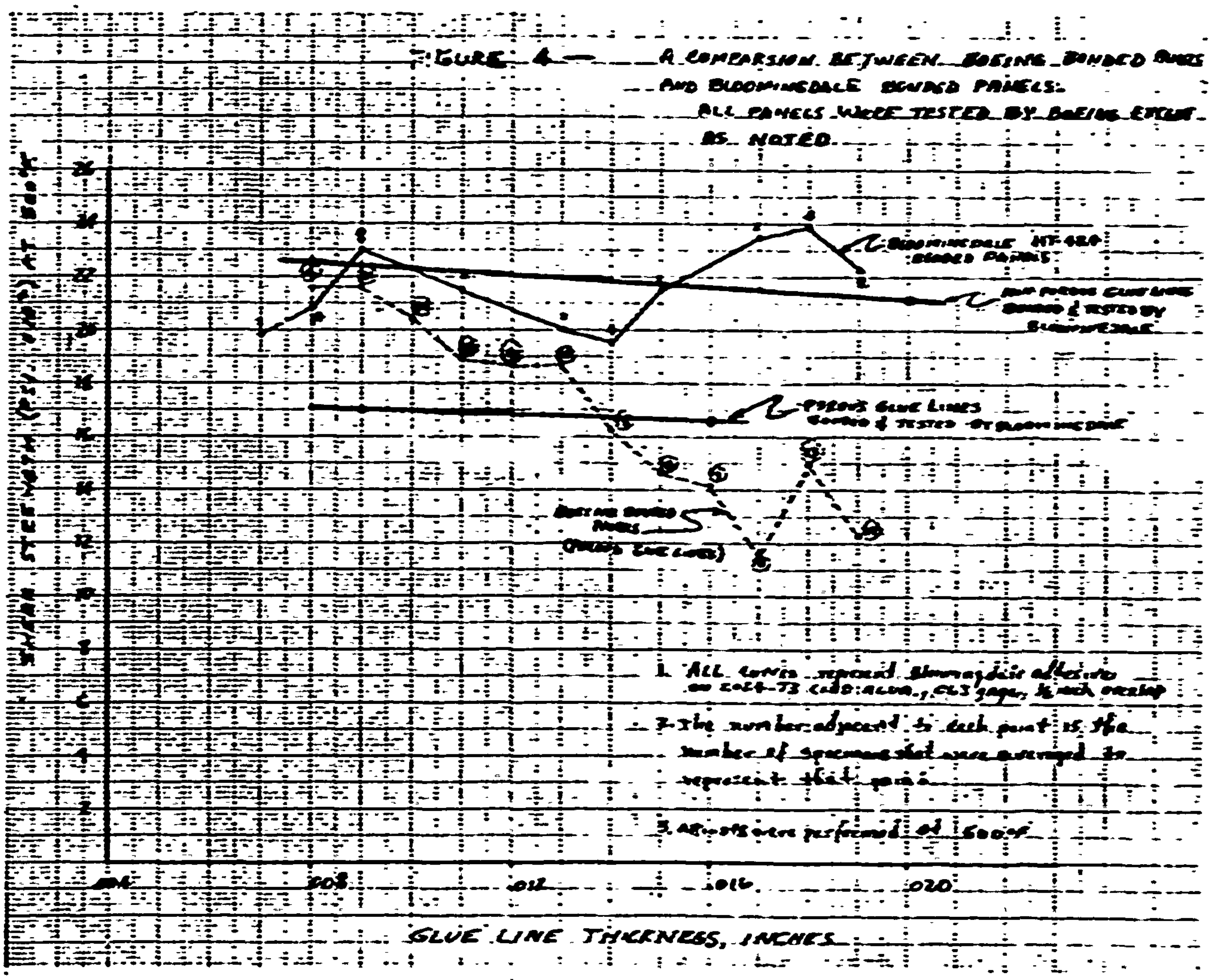
AUTHOR: K. Methvin DATE: 8-24-61 PAGE 6

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



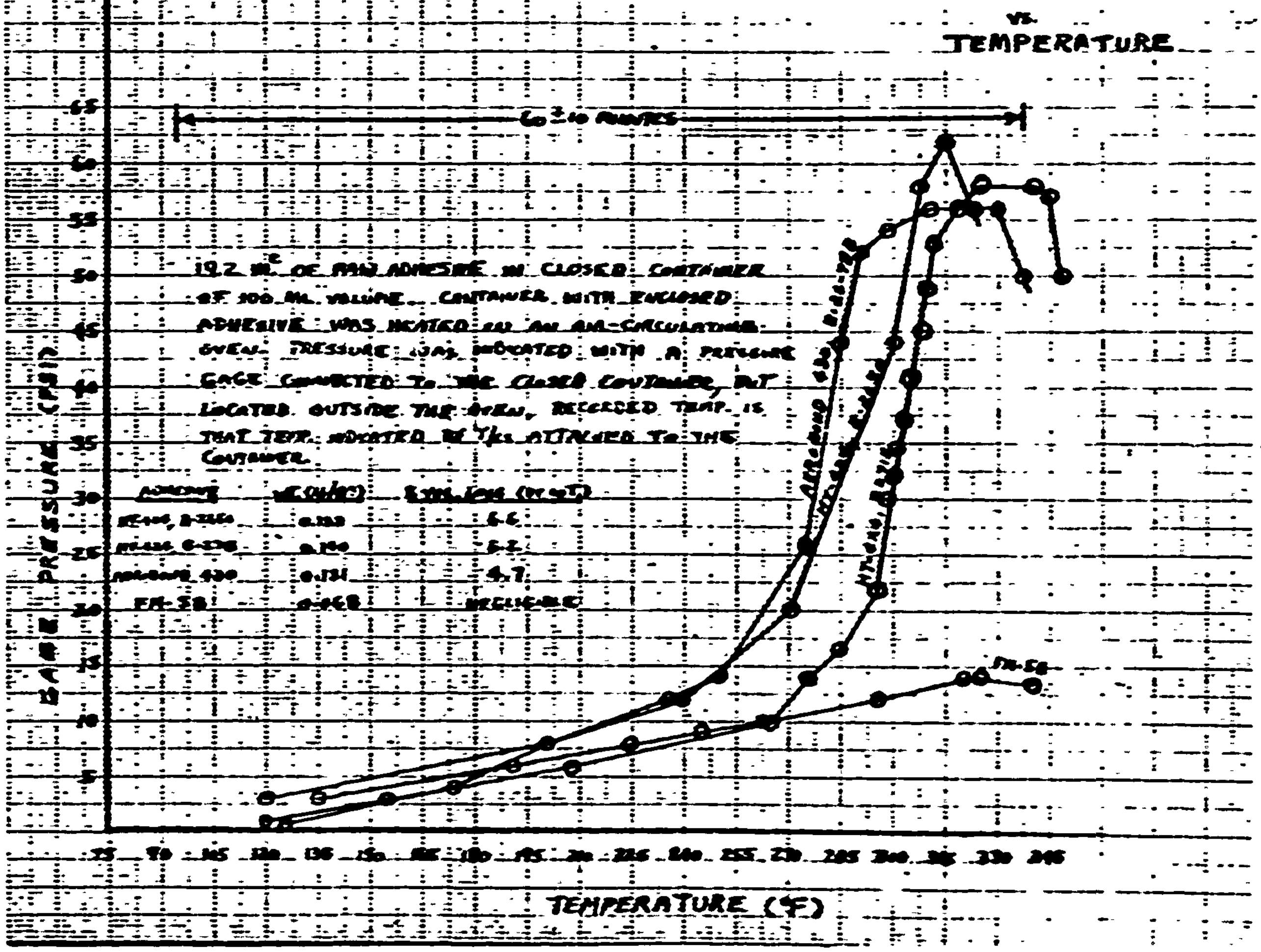
I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

FIGURE 5 - TOTAL PRESSURE vs. TEMPERATURE



I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

	TEST TEMPERATURE		
	475°F	500°F	525°F
SHEAR (PSI)	1738.5	1676	1600

	CIRCULATING AIR OVEN	
	SLOW HEAT-UP	FAST HEAT-UP
500°F SHEAR (PSI)	1640	1611

	JAWS OUT OF OVEN		
	30 SECS.	60 SECS.	90 SECS.
500°F SHEAR (PSI)	1555	1541	1568

	SOAK TIME AT 500°F			
	5 MIN.	10 MIN.	20 MIN.	60 MIN.
500°F SHEAR	1640*	1642.5	1636	1574

*Average of 9 specimens. All other values are averages of 10 specimens.

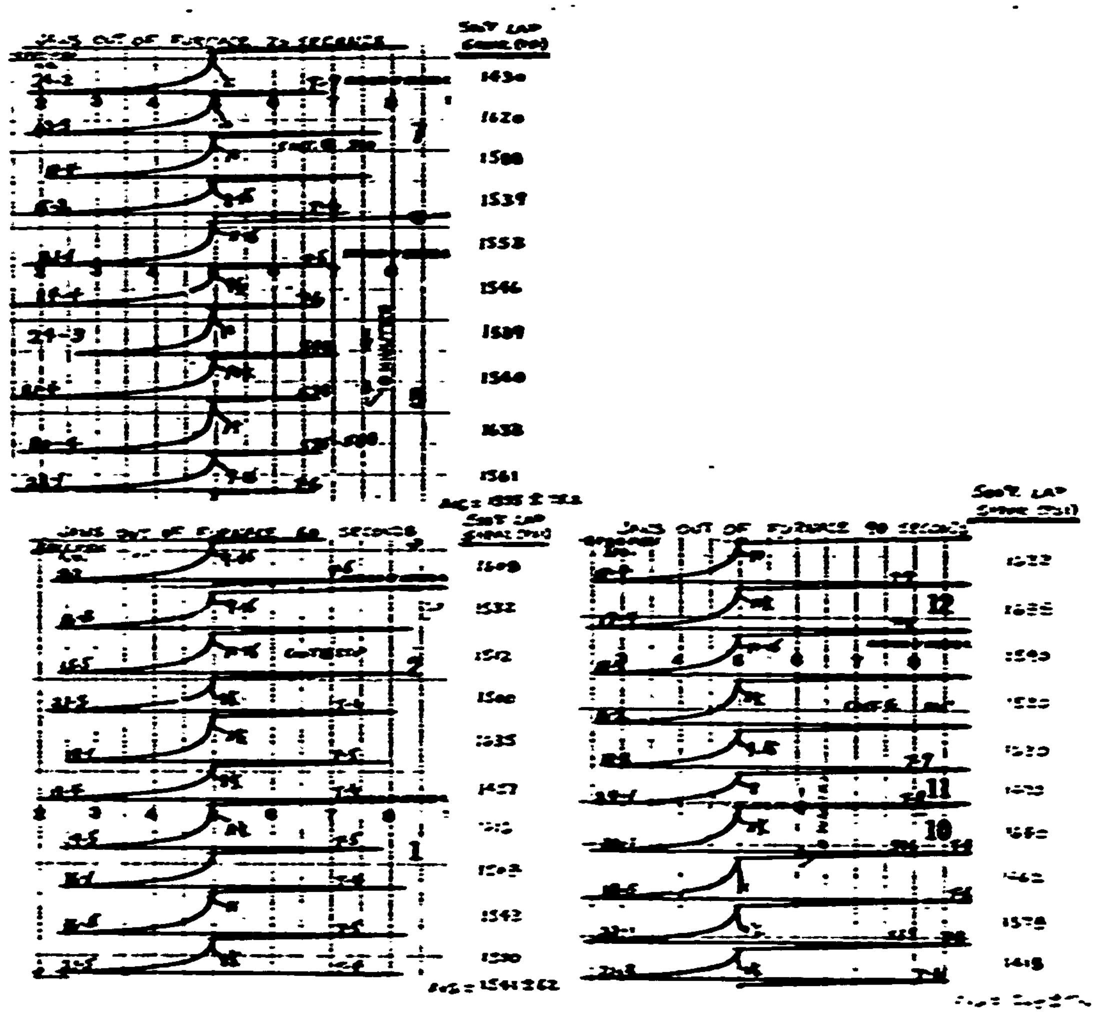
TABLE 1

1 T/C clamped to center of lower half of all test specimens within 1/4 inch of adhesive flash. Calibration work was done with this T/C plus a T/C embedded in the bond. (Embedded T/C read 5°F lower than ext. T/C).

FIGURE 6 - Position of T/C on Test Specimen

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

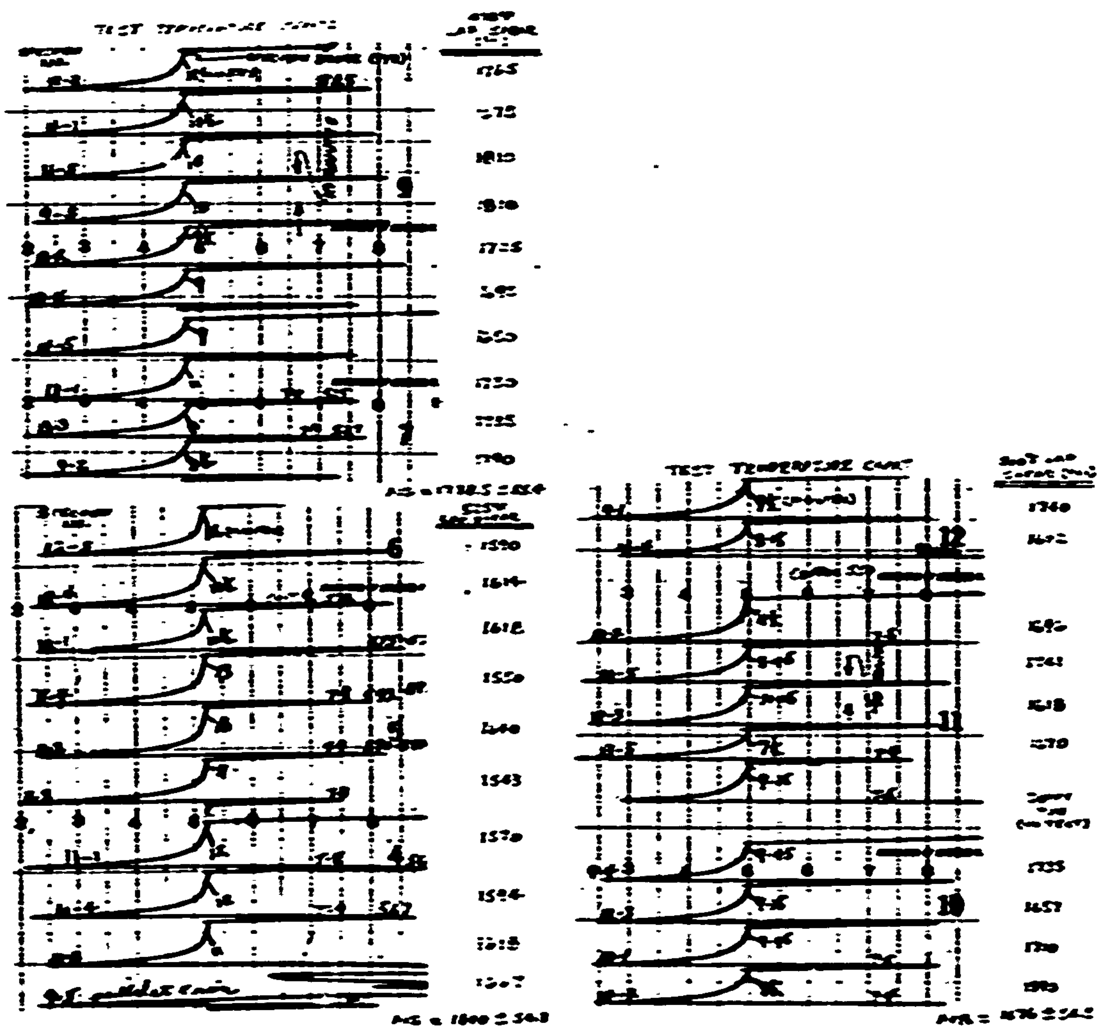


Bloomingdale HT-424 bonds made with .063 clad aluminum - tested in lap shear at 500°F in a Marshall furnace - Effect of heat-up rate (by varying heat loss of jaws).

FIGURE 7

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424

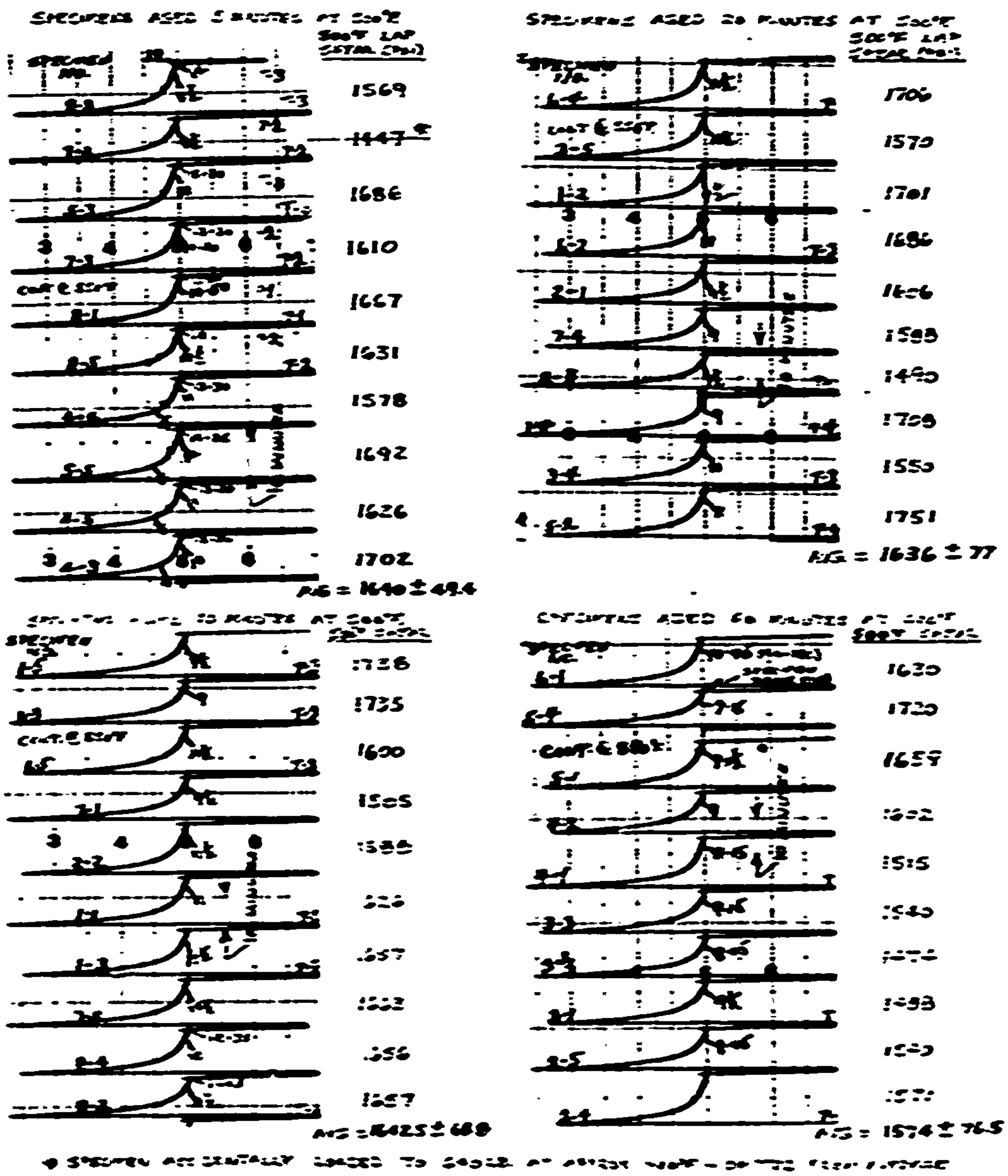


Effect of temperatures on Bloomingdale HT-424 bonds made with .063 clad aluminum - tested in lap shear in Marshall furnace (Jaws out of furnace 60 seconds).

FIGURE 8

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424



Effect of time at 500°F on Bloomingdale HT-424 bonds made with 0.063 clad aluminum - tested in lap shear at 500°F in a Marshall furnace. (jaws out of furnace 60 seconds).

FIGURE 9

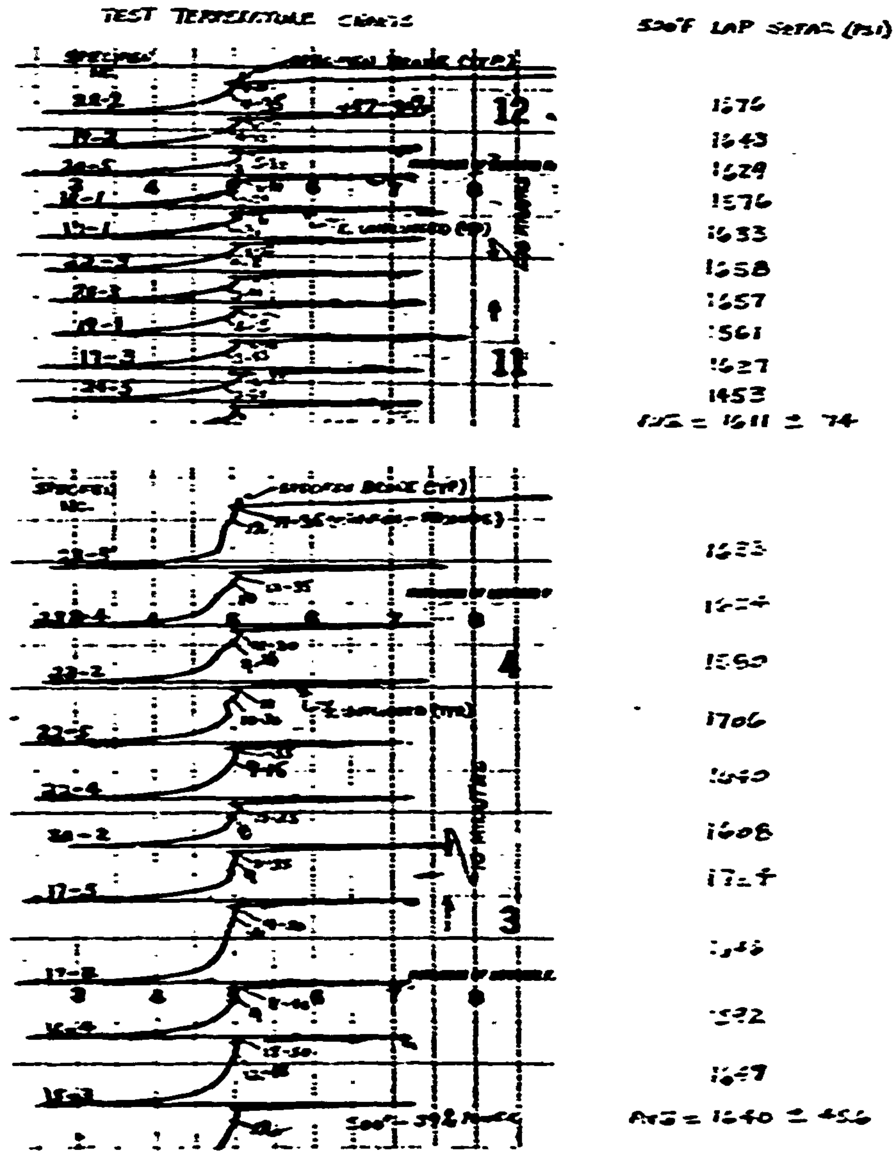
AUTHOR: K. Mechwin **DATE:** 8-24-61 **PAGE** 12

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesives, Structural, HT-424



Bloomingdale HT-424 bonds made with 0.063 clad aluminum - tested in lap shear at 500°F in a circulating air oven - effect of heat-up rate.

FIGURE 10

AUTHOR: K. Methvin **DATE:** 8-24-61 **PAGE** 13

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical
Information not available due to lack of need for Boeing-Wichita's investigating this property.

AUTHOR: K. Methvin **DATE:** 8-24-61

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. **PRINCIPAL PROPERTIES:**

C. Electrical
Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

D. Chemical
Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, HT-424

VI. RECOMMENDED USES:

HT-424 is used extensively in bonding non-perforated aluminum sandwich for the B-52. It is recommended that the data obtained in this program be used by Materials and Process Unit Engineers as a guide in advising Design personnel and subcontractors.

VII. SUPPLIER AND TRADE NAME:

A. HT-424 Adhesive is the trade name of this material. It is supplied by Bloomingdale Rubber Company of Aberdeen, Maryland.

B. HT-424 is available in continuous tape form, approximately 38 inches wide and .012 to .014 inch thick. It is also available in other thicknesses supported on a glass cloth carrier. Refrigeration at 0°F is recommended.

C. HT-424 costs approximately $0.65/sq.ft. in large production quantities.

VIII. REFERENCES:

A. "Investigation of BMS 5-17 Adhesive Cure Cycle", Job Report AP-2-27 (Boeing-Wichita) dated 6-24-59, by K. Kethvin.

B. "Room Temperature Exposure of BMS 5-17 Adhesive", Job Report AP-2-31 (Boeing-Wichita) dated 6-25-59, by K. Kethvin.

C. "Glueline Thickness versus Shear Strength", Job Report SA-2-169 (Boeing-Wichita) dated 10-22-58, by C. Edwards.

D. "Investigation of Variables in 500°F Lap Shear Test", Job Report AP-2-174 (Boeing-Wichita) dated 8-30-61, by K. Kethvin.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

III. **GENERAL DESCRIPTION:**

The objective of this program was to determine the effect of certain variables on cured adhesive bonds made with AF-30 adhesive and EC-1593 primer.

IV. **DEVELOPMENTAL BACKGROUND:**

AF-30 tape and EC-1593 primer adhesives have been approved by Boeing for use as a structural bonding system for aluminum and magnesium on flight vehicles. The adhesive system is qualified under MIL-A-5090.

Boeing's specifications governing the use of this adhesive system specify the minimum requirements in BMS 5-42 and BAC 5462. There are many conditions specified by design that cannot be reasonably covered by general usage specifications. Examples of such conditions are use of varying skin gages and difference in curing facilities throughout the industry. It was felt advisable to determine the effect of some of these variables on joint strength so that advice could be given to subcontractors and design groups when needed.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. The relationship between peel strength and lap shear strength for various bond line thicknesses is given in Figure 1. It appears that it is possible to tailor a bond for the optimum combination of shear and peel strength by controlling the thickness of the AF-30 adhesive.

2. The effect of width of overlap and metal thickness on lap shear strength of AF-30 (with and without EC-1593 primer) is shown in figures 2 and 3.

3. The effect of bond line pressure on one-half inch overlap shear bonds with Dow 7 magnesium coated with zinc chromate primer is shown in Figure 4. An optimum bonding pressure was not found. Bonding may be accomplished with equal results on test panels between 20 and 120 psi.

4. The effect of using positive pressure only and vacuum pressure in curing AF-30 bonds is shown in Figure 5. There appears to be no difference in one-half inch overlap bonds whether vacuum is used or not. In areas as large as one square foot use of vacuum during cure results in higher strengths than when no vacuum is used. A cure pressure of 40 psi was used.

5. The effect of cure temperature and cure time on one-half inch overlap bond strength is shown in Figure 6. Data presented was taken with AF-30 adhesive on clad .063 aluminum.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. **Mechanical**

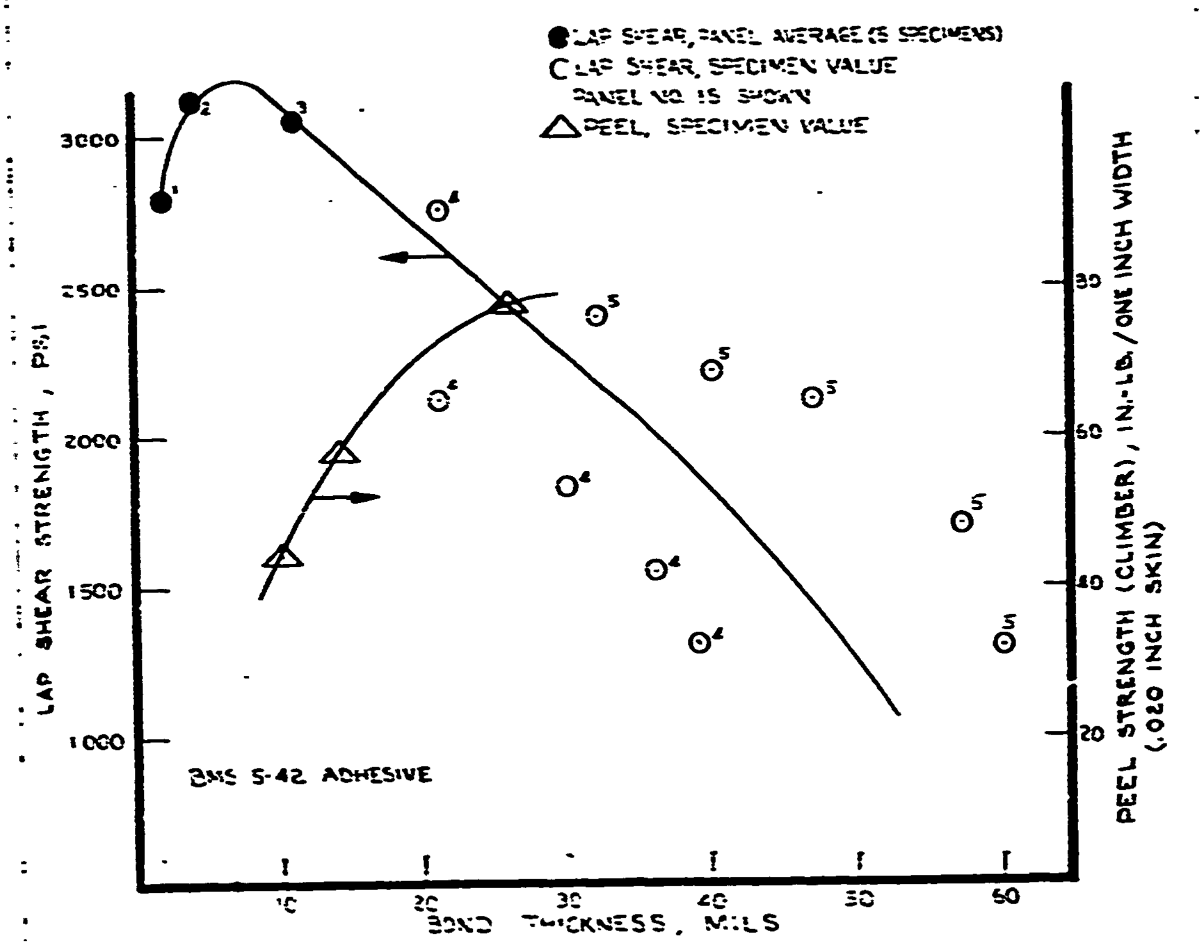


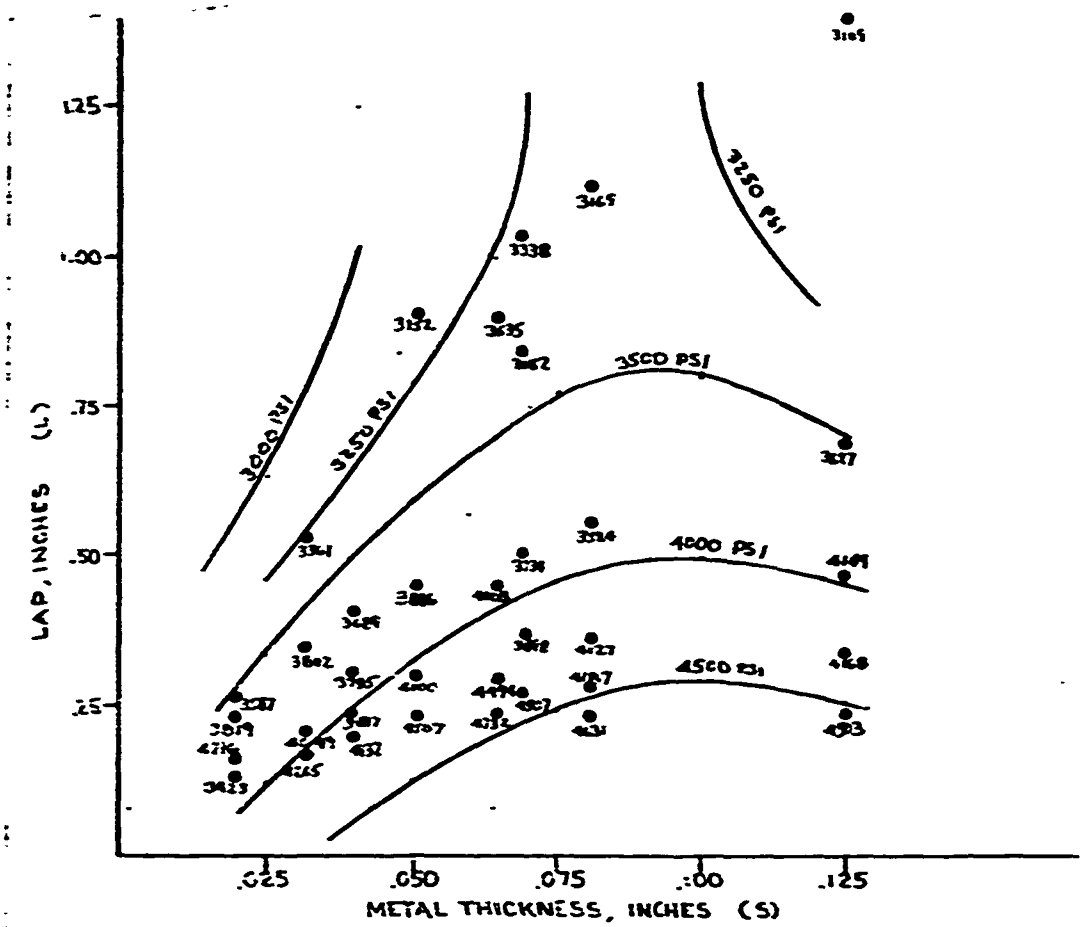
FIGURE 1

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. Mechanical



2024-T3 CLAD AF-9330 ADHESIVE SYSTEM
FITTED EQUATION: $\hat{Y}(PSI) = 3626 - 2880L + 32,728S + 1284L^2 - 152,367S^2 - 5593LS$

CONTOUR DIAGRAM LAP SHEAR STRENGTH, LAP VS. THICKNESS CLAD ALUMINUM ALLOY, AF-9330 ADHESIVE

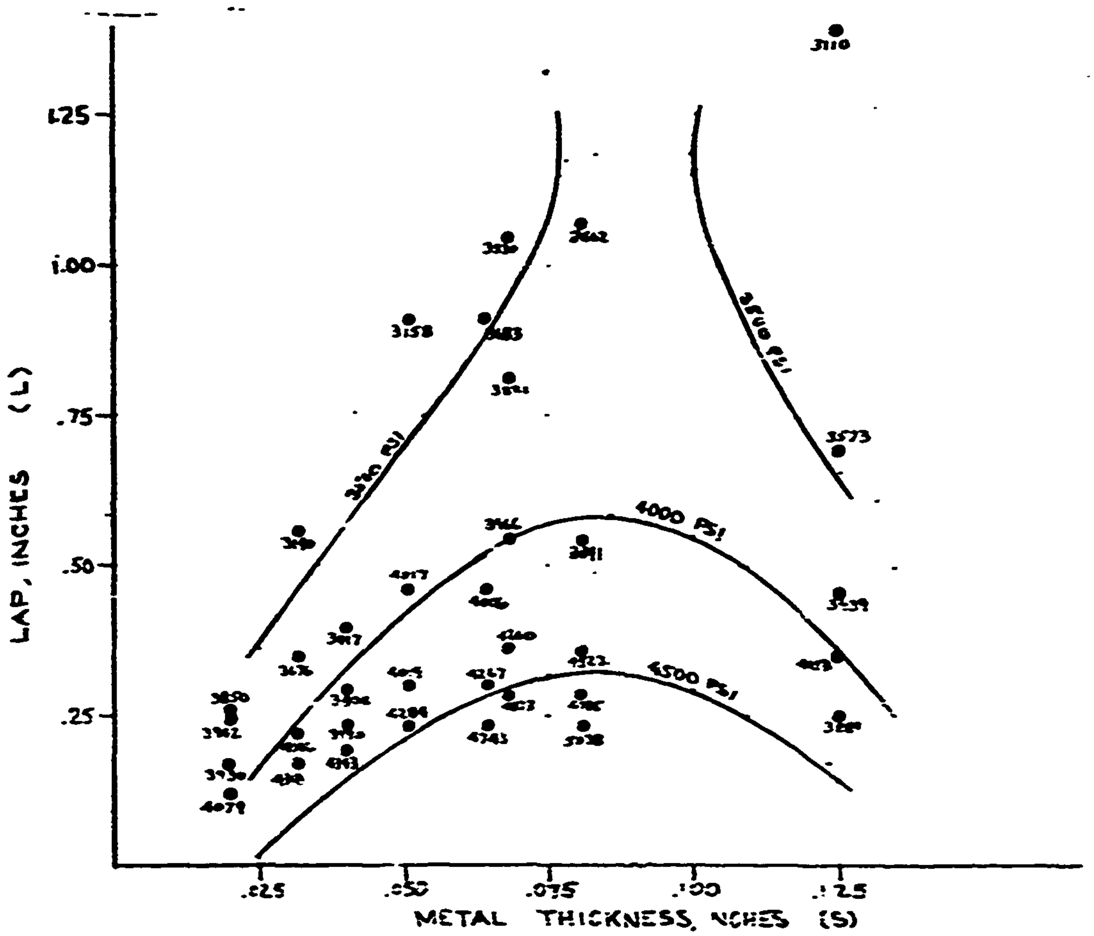
FIGURE 2

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. Mechanical



2024-T3 CLAD AF-30 ADHESIVE
FITTED EQUATION: Ŷ(PSI)=3633−3372 L+43,635S+ [illegible] L²−260,834 S²+327[illegible] LS

CONTOUR DIAGRAM LAP SHEAR STRENGTH, LAP VS. THICKNESS CLAD ALUMINUM ALLOY, AF-30 ADHESIVE

FIGURE 3

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

30 MIN. CURE

310°F				(6)(6)(3)(5)		320°F				(7)(7)(4)(7)		330°F				(1)(2)(3)(1)	
20PSI	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
2930	2955	2777	2965	2924	2753	2722	2737	2831	2781	2738	2936	2886	2767	2773	2867	2855	2935
3055	2963	2994	3159	3246	2937	2934	3100	3074	2932	3091	3042	2507	2355	2545	2696	2819	2633
3014	2728	2954	3024	3077	2972	3059	3022	2954	3056	3318	3123	2950	2931	2946	3088	2597	3016
2942	2940	2 5①	3137	2397	3135	3093	3070	3125	2753	2861	3020	2873	2791	3047	2891	2931	2875

40 MIN. CURE

310°F				(7)(1)(7)(3)		320°F				(3)(4)(1)(2)		330°F				(2)(3)(3)(2)	
20PSI	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
27[illegible]	2793	2777	2865	2912	2865	3056	3083	2895	2954	3010	2443	2777	2698	2705	2789	2837	2712
2947	3028	2750	2923	2296	2958	3189	3080	2946	3151	2936	3059	3000	2990	2763	2996	3129	3250
2940	3025	3191	2823	3125	2950	2976	2940	2871	3067	2901	2932	2926①	2826①	2934②	2987①	2335②	2313②
3235	3155	2942	3167	3084	3155	2952	2921	3046	3028	3118	2357	3115	3012	3133	3167	3015	2723

50 MIN. CURE

310°F				(4)(5)(9)(1)		320°F				(3)(3)(2)(3)		330°F				(5)(4)(5)(3)	
20PSI	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
3003	3125	2801	3565	3212	2930	2531	2337	2397	2901	3101	2707	2728	2704	2521	2913	3057	2725
2990	3008	2724	2733	2340	2367	2393	2901	2311	2319	2355	2974	2337	2349	2301	3018	2370	3026
2945	2785	2555	2903	2720	2774	3115	3112	3048	3066	3105	3137	2607	2974	2916	2988	2922	2817
2917	2743	3020	2796	2757	2904	2758	2939	2986	3038	3014	2935	2[illegible]1	2929	2920	3149	2395	3097

① NO PRESSURE ON BONDLINE - CATEGORY AVERAGE AS SHOWN USED FOR ANALYSIS.
② BONDED AT 345°F - CATEGORY AVERAGE AS SHOWN USED FOR ANALYSIS.
NOTE: NUMBERS IN PARENTHESES CORRESPOND TO RUN NO. FOR FIRST, SECOND, THIRD, AND FOURTH REPLICATE RESPECTIVELY. SPECIMEN CODE: REPLICATE NO.—RUN NO.—BOND PRESSURE—SPECIMEN NO.

AVERAGE PANEL STRENGTH - LAP SHEAR, PSI

FIGURE 4

AUTHOR: K. Methvin DATE: 12 July 1961

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

RESULTS

4x6x.064 CLAD ALUM — ½ INCH BONDED OVERLAP			
16" VACUUM USED		NO VACUUM USED	
PANEL NO.	SHEAR (PSI)*	PANEL NO.	SHEAR (PSI)*
2-1	3396	1-1	3430
2-2	3485	1-2	3336
3-1	3545	4-1	3507
3-2	3451	4-2	3296
5-1	3487	7-1	3261
5-2	3460	7-2	3131
6-1	3146	8-1	3412
6-2	3569	8-2	3485
AVERAGE	3359	AVERAGE	3442

* AVERAGE OF 5 SPECIMENS

12x12x.040 CLAD ALUM — ENTIRE AREA BONDED			
16" VACUUM USED		NO VACUUM USED	
PANEL NO.	SHEAR (PSI)✫	PANEL NO.	SHEAR (PSI)✫
2	3301	1	3252
3	3255	4	2278
5	3015	7	2957
6	3240	8	2517
AVERAGE	3228	AVERAGE	2751
		9	2725
		10	2801
		AVERAGE	2763

✫ AVERAGE OF 10 SPECIMENS (SHIMS TO ½ INCH OVERLAP AS DESCRIBED IN PROCEDURE). PANEL NUMBERS 9 AND 10 WERE BONDED WITH A TOOL CONSISTING OF A 1" THICK ALUM PLATE BETWEEN THE PART BEING BONDED AND A STEEL BLADDER USED TO APPLY PRESSURE (COMPRESSED AIR). PANELS 1 THROUGH 8 HAD PRESSURE APPLIED DURING BONDING WITH THE SAME STEEL BLADDER, BUT THE TOOL BETWEEN THE PART AND THE BLADDER WAS AN ALUM-FACED PLYWOOD 1" THICK.

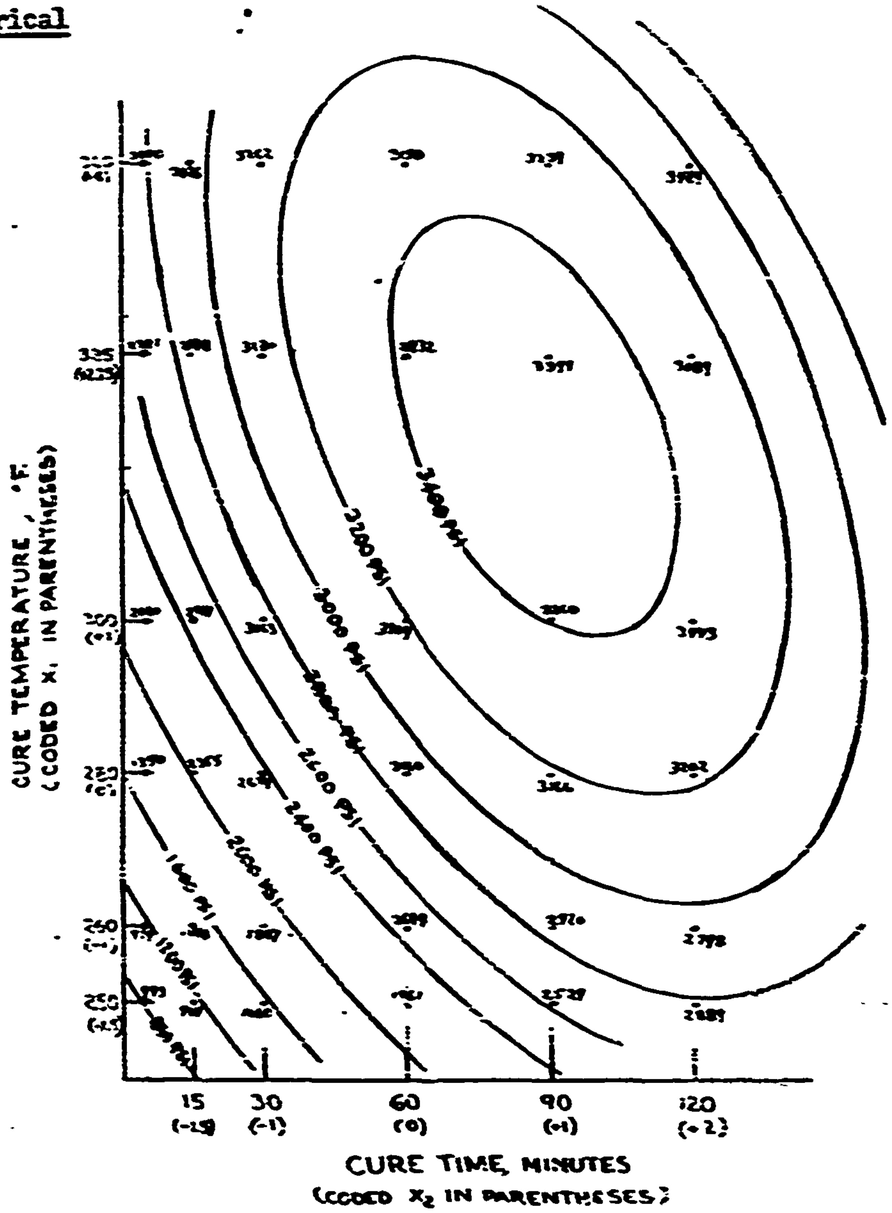
FIGURE 5

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

A. Electrical



FITTED EQUATION: $\hat{Y}(PSI) = 2891.491 + 366.8217 x_1 + 466.2654 x_2 - 64.0172 x_1^2 - 120.3[illegible] x_2^2 - 61.[illegible] x_1 x_2$
(USING CODED VALUES OF x_1 AND x_2)
NOTE: TEST VALUES SHOWN ON DIAGRAM.

FIGURE 6

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-~-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

B. **Thermo Physical**

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

C. Electrical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

V. **PRINCIPAL PROPERTIES:**

D. **Chemical**

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. **MATERIAL NAME:** Adhesive, Structural, AF-30

VI. **RECOMMENDED USES:**

It is recommended that the data obtained be used by Materials and Process Engineers as a guide in advising design personnel and Sub-Contractors.

VII. **SUPPLIERS AND TRADE NAMES:**

A. The supplier designation of the adhesive system used in these tests is AF-9330 adhesive by Minnesota Mining and Manufacturing Company.

B. **Availability**

EC-1593 primer is available in a 10% solids form. AF-30 tape is available in sheet form up to 30 inches wide and .010 to .014 inches thick.

C. **Costs**

AF-30 costs approximately \$0.75/ft.^{2}. EC-1593 costs approximately \$5.60/gal. (depending on quantity).

VIII. **REFERENCES:**

1. "Mechanical Properties of Structural Adhesives", Job Report AP-1-22 (Boeing-Wichita), dated 23 November 1960, by Don Brown.

2. "Bondline Pressure for AF-30 Bonded Magnesium", Job Report AP-2-68 (Boeing-Wichita), dated 1 September 1959, by Don Brown.

3. "Cure of AF-9330 Adhesive Without Vacuum", Job Report AP-2-119 (Boeing-Wichita), dated 1 July 1960, by K. Methvin.

4. "Joint Factors of Metal Bonded Joints", Job Report AP-3-40 (Boeing-Wichita), dated 25 January 1960, by Don Brown.

5. "Effect of Various Cure Cycles on AF-30", Job Report SA-2-170 (Boeing Wichita), dated 6 January 1959, by Don Brown.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** Hi-Temperature Lubricants

III. **GENERAL DESCRIPTION:**

The object of this program was to investigate the thermal capabilities of various available experimental lubricants.

IV. **DEVELOPMENTAL BACKGROUND:**

A considerable effort is currently being made by various Military and Industrial groups to obtain, develop, synthesize and compound lubricants that are suitable over a greater temperature range than those covered by present Military Specification.

This report represents some of the work presently being conducted by Boeing toward the evaluation of a few of the available experimental high temperature lubricants. Various laboratory bench tests were used to establish the stability, Wear characteristics, and physical and chemical properties of the materials.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

1. Navy Gear Wear Test Data (at room temperature)

Code No.	Wt. Loss of Brass Gear MG/1000 rev., 5 lb wt.
299-56	27.9
316-57	5.1
317-57	10.4
318-57	3.3
319-57	1.3
320-57	9.0
321-57	1.2
395-57	30.6
79-60	12.8
273-60	11.1
292-60	16.9
293-60	1.3

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

2. Bearing Performance Test

a. Method 331.1 per FTMS 791
Fixed Load - 3 lb Radial, 5 lb Thrust
Fixed Speed - 10,000 rpm
Bearing Material - 52100 Tool Steel, Cage
Cage Material - AISI 1008 Pressed Steel

Code No.	Bearing Temp °F	Total Hours	Termination Reason	Bearing Condition
298-57	250	324	Excessive Temp. Rise.	False Brinelling of race. Shaft out of balance.
387-57	300	677.8	Excessive Temp. rise. Grease was dry.	Cage worn, slight discoloration from heat. Balls slightly rough.
387-57	350	163.7	Excessive Temp. rise. Grease was dry.	Cage worn, broken. Heavy discoloration on ball path from heat.
387-57	325	158	Excessive Torque at start of cycle.	Cage worn. Ball path discolored from heat.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

2. b. Method 333 per FTMS 791
Fixed Load - 5 lbs Radial, 5 lb Thrust
Fixed Speed - 10,000 rpm
Bearing Material - 18-4-1 Tool Steel
Cage Material - Silver Plated Copper Beryllium (CRC L-35)
(For Graph of the following data see Figure 1)

Code No.	Bearing Temp °F	Total Hours	Termination Reason	Bearing Condition
316-57	490	120	Excessive Torque increase at start of cycle. Grease ran from bearing.	Cage worn, flaking of silver plate. Heavy discoloration from heat.
316-57	450	129	Excessive heat rise. Grease ran from bearing.	Cage worn, flaking of silver plate. Discolored from heat.
316-57	400	543.5	Excessive heat rise.	Bearing slightly rough, discolored from heat. Cage worn flaking of silver plate.
318-57	450	157.5	Excessive heat rise.	Bearing jammed badly burned.
[illegible]9-60	350	12[illegible]	No failure - discontinued	

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BOEING AIRPLANE COMPANY
WICHITA DIVISION

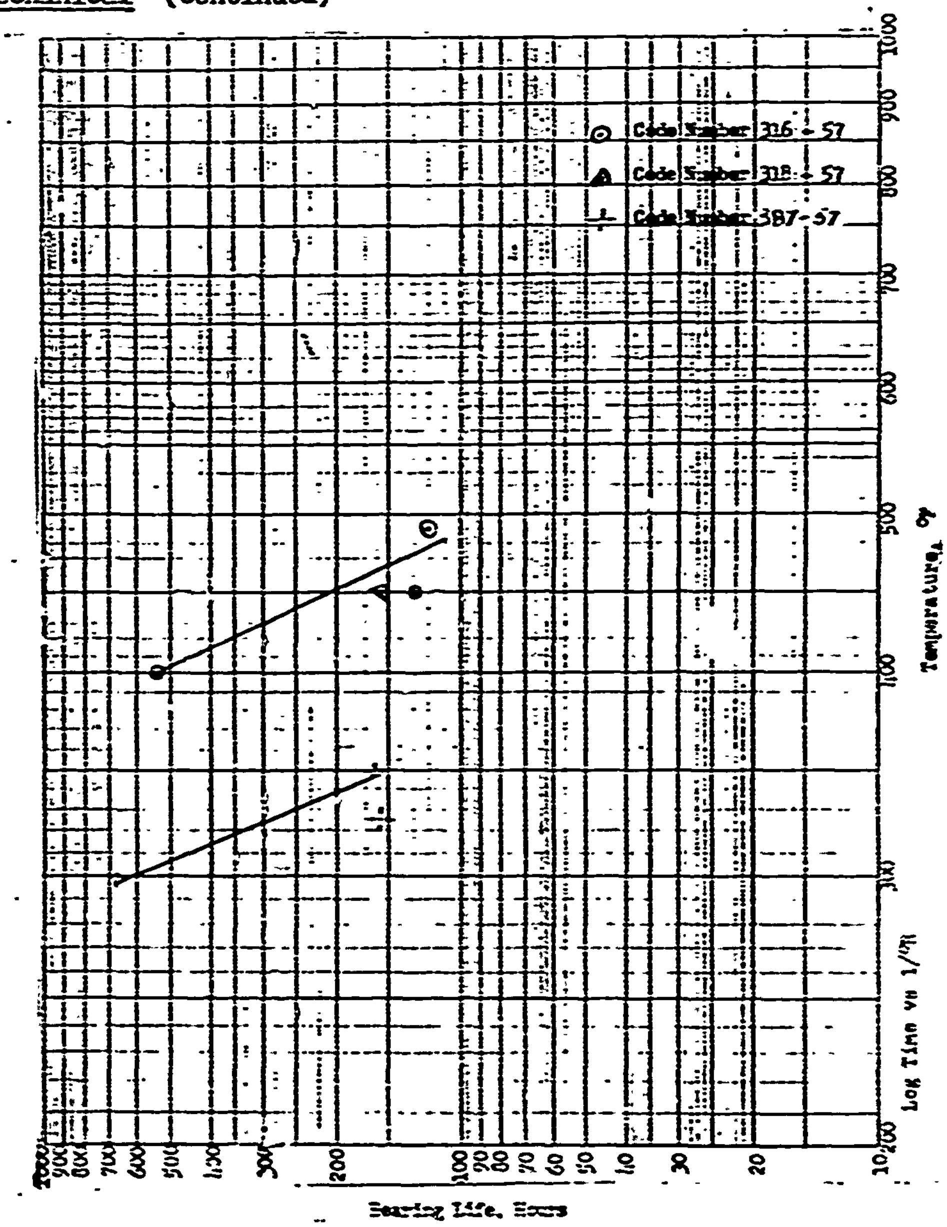
AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



HIGH TEMPERATURE BEARING TESTS
(FTMS-791, METHOD 333)

FIGURE 1

AUTHOR: C. E. Haines DATE: 9-15-61 PAGE 5.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers   **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

V. **PRINCIPAL PROPERTIES:**

B. **Thermophysical**

Code No.	Dropping Point, °F.	Oil Separation % Wt. Loss, 30 Hours @212°F	Evaporation % Wt. Loss, 22 Hours @400°F.	Oxidation Resistance lb. Drop 100 Hrs. @210°F	Corrosion Cu. Strip, 24 Hrs. @212°F (ASTM Class)
299-56	524			0	1 a
316-57	504	4.62		0	2 c
317-57	482	4.74	1.82	0	None
318-57	530	5.54	2.67	0	1 a
319-57	652	3.16	8.53	.2	1 b
320-57	501	3.37	3.62	1.5	Liq. ph - 4 a Vap. ph - 1 b
321-57	700	3.86		12	Liq. ph - None Vap. ph - 1 b
396-57	422			0	
79-60	362	3.04	6.03		
273-60	[illegible]	1.45	[illegible]		
290-60	120				
291-60	500		13.35		
292-60	408	2.88	9.29		
293-60	500		51.90		

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

B. Thermophysical (continued)

Results of Thin Film Evaporation Tests, 24 Hrs. at Temperature

Code No.	200°F	300°F	350°F	400°F	450°F	500°F
299-57	a	b	c	d	g	h
316-57	a	a	b	b	c	d
317-57	a	b	c	d	e	f
318-57	a	b	c	d	e	f
319-57	b	g	h	h	h	h
320-57	a	b	c	h	h	h
321-57	c	f	g	g	g	g
396-57	a	b	c	h	h	h
387-57	b	c	d	f	f	h
79-60			a	b	c	d
273-60			a	a	b	c
291-60			b	c	e	f
292-60			b	c	d	f
293-60			c	d	h	h

Rating Code

a. Very little change.
b. Slightly heavier consistency
c. Definitely heavier consistency
d. Extremely heavier consistency
e. Dried, thin soft residue
f. Hard varnish like residue
g. Dry brittle residue
h. Ash or powdery residue

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

V. **PRINCIPAL PROPERTIES:**

C. Electrical

The electrical properties of these materials have not been determined by Boeing-Wichita since such information would be of little or no value from a lubricant standpoint.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES:

D. Chemical

Classification of Fluid and Thickener

Code No.	Fluid Type	Thickener Type
299-56	Silicone	Lithium Soap
316-57	Silicone	Non Soap
317-57	Silicone	Aryl Urea
318-57	Silicone	Aryl Urea
319-57	Petroleum	Clay Type
320-57	Silicone	Carbon Black
321-57	Petroleum	Clay Type
369-57	Silicone	Non Soap
79-60		
273-60	Silicone	Organic
290-60	Petroleum	Graphite
291-60	Silicone	Aluminum Organic Complex
292-60		
293-60		

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

VI. **RECOMMENDED USES:**

These materials are intended for use in high temperature grease applications. Probable upper temperature limitations for satisfactory bearing operation are:

Code No.	Temperature, °F.	
299-57	300	(2)
316-57	375	(1)
317-57	300	(2)
318-57	300	(1)
319-57	250	(2)
320-57	300	(2)
321-57	200	(2)
396-57	300	(2)
387-57	300	(1)
79-60	350	(1)
273-60	450	(2)
291-60	350	(2)
292-60	400	(2)
293-60	300	(2)

(1) Temperature limit for 600 + hours on High Temperature Bearing Test per FTMS No. 791 Method 333.

(2) Estimated from Thermophysical Properties.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

VII. **SUPPLIERS AND TRADE NAMES:**

Code No.	Trade Name	Supplier
299-57	Versilube G-300	General Electric Company
316-57	2-1176A	Shell Oil Company
317-57	Supermil ASU-M100	Standard Oil Company
318-57	Supermil ASU-M40	Standard Oil Company
319-57	Stanomelt 321	Standard Oil Company
320-57	D.C. 41	Dow Corning Corporation
321-57	Cactus Brand Sotol	Southwestern Petroleum Co.
396-57	TG-3195	The Texas Company
397-57	MIL-G-3545, Lubricating Grease	Sinclair Refining Company
79-60	ETR-H	Shell Oil Company
273-60	Mobiltemp 67	Socony Mobil Oil Company, Inc.
290-60	HiTemp 2409	E.F. Houghton and Company
291-60	MLG59-509	E.F. Houghton and Company
292-60	Cosmolube 5100	E.F. Houghton and Company
293-60	Cosmolube 5200	E.F. Houghton and Company

AUTHOR: C. E. Haines DATE: 9-15-61 PAGE 11.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. **MATERIAL NAME:** High Temperature Lubricants

VIII. **REFERENCES:**

A. High Tempe: ure Bearing Lubricants, Boeing Document D3-1625, C.W. Dufur, C.R. Sponsl - and R.L. Pinckney, 23 June 1958.

B. Federal Test Method Standard No. 791, 15 December 1956.

C. "Development and Evaluation of High Temperature Greases", WADC Technical Report 53-53, Part IV, E. Swakon, Standard Oil Company (Indiana). Contract No. AF33(038)-23687, Project No. 3044, September 1956.

D. "Temperature Limitations of Various Lubricants", Boeing Research Job No. SM-1-5 (in progress).

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquers

III. **GENERAL DESCRIPTION:**

A number of enamels and lacquers were investigated to determine their resistance to temperatures up to 450°F for a period of 30 minutes.

IV. **DEVELOPMENTAL BACKGROUND:**

A. Materials Tested

Gloss Enamels, MIL-E-7729

1. ANA #502, Insignia Blue
2. ANA #505, Light Yellow
3. ANA #506, Orange Yellow
4. ANA #509, Insignia Red
5. ANA #511, White
6. ANA #515, Black

Gloss Lacquers, MIL-L-7178

7. ANA #502, Insignia Blue
8. ANA #506, Orange Yellow
9. ANA #509, Insignia Red
10. ANA #511, White
11. ANA #515, Black

Camouflage Lacquer, MIL-L-6805

12. ANA #604, Black

B. Test Procedure

The enamels and lacquers were applied to clean, unprimed panels (aluminum alloy, QQ-A-287, 7075-T6 alclad, or stainless steel alloy, QQ-S-766a, Type 321), aged a minimum of 48 hours at room temperature, and then placed in an oven and held at the designated temperature for 30 minutes. After cooling, the panels were examined.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquers

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Information was not obtained due to lack of need for Boeing-Wichita Investigation of this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquer

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

The thermophysical properties of these enamels and lacquers are shown in Table I.

The inconsistencies in the results of the tests on Sample No. 12 at 400°F and 450°F are attributed to variations in the material and/or variations in the test conditions.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquer

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

Sample No.	Material	Color	Temperature, °F				
			200	300	350	400	450
1	Enamel	Insignia Blue	S	S	S	C,LG,S	C,LG,S
2	"	Light Yellow	S	S	LG,S	C,LG,S	C,LG,S
3	"	Orange Yellow	S	S	LG,S	C,LG,S	C,LG,S
4	"	Insignia Red	S	S	S	C,LG,S	C,LG,S
5	"	White	AP*	AP,C,S	C,S	C,LG,S	C,LG,S
6	"	Black	AP*	S	S	LG,S	LG,S
7	Lacquer	Insignia Blue	AP*	S	LG,S	C,LG,S	C,LG,S
8	"	Orange Yellow	AP*	S	LG,S	C,LG,S	C,LG,S
9	"	Insignia Red	S	S	S	C,S	C,S
10	"	White	AP*	LG,S	LG,S	C,LG,S	C,LG,S
11	"	Black	AP*	S	S	LG,S	C,LG,S
12	"	Black	AP*	S	S	AP,U	AP,S

KEY: AP - Adhesion Poor
C - Color Changing
LG - Loss of Original Gloss
S - Satisfactory
U - Unsatisfactory

* Probably due to poor initial adhesion due to lack of metal surface pre-treatment.

Effect of 30 Minutes Exposure at Various Temperatures

TABLE I

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquers

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Enamels and Lacquers

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

VI. RECOMMENDED USES:

It is recommended that the information in Table I be used as a guide in predicting the probable temperature limitations of the enamels and lacquers tested.

VII. SUPPLIERS, AVAILABILITY, AND COSTS:

A. Suppliers

Enamel No. 5: Rinshed-Mason, Incorporated
Milford at Epworth
Detroit 10, Michigan

Enamel No. 3, 4, and 6; and lacquer No. 11:
Andrew Brown Company
5413 South District Blvd.
Los Angeles, California

Enamel No. 1: W. P. Fuller Company
Mission and Beale Streets
San Francisco, California

Enamel No. 2: The Glidden Company
10999 Madison Avenue
Cleveland 2, Ohio

Lacquers No. 7, 8, 9, 10, and 12:
Emrar, Incorporated (Formerly Titanine, Incorporated)
1424 East 25th Street
Wichita, Kansas

B. Availability

All these enamels and lacquers are currently available from their manufacturers.

C. Cost

These enamels and lacquers are all in the medium price range.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

VIII. REFERENCE:

1. Boeing Company Materials and Process Unit Document D3-1598, "Temperature Limitati of Marking Materials (Phase I)".

AUTHOR: L. R. Mason Date: 9-14-61 PAGE 8

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

III. GENERAL DESCRIPTION:

The organic coatings are used for protective and decorative purposes on the exterior or interior of aircraft. The organic coatings consists of a primer and an enamel. For interior purposes the primer alone is used and for exterior purpose both the primer and enamel are used as a system.

The materials for the organic coating are controlled by Boeing Material Specification 10-15. The only restriction on materials is that the vehicle used in the formulation of the primer and enamel shall be of a two component epoxy type. The color of the primer may be either off-white, light yellow or green. The color of the enamel is untinted white conforming to AN 511 of ANA Bulletin 166. Exact pigments to be used either for the primer or enamel is not restricted. In general, the formulation and specific properties will vary from manufacture to manufacture.

The epoxy organic coatings a : applied by conventional spray equipment. Application by brush or air-less spray equipment is not recommended.

IV. DEVELOPMENT BACKGROUND:

The epoxy organic coatings were developed under Boeing Company Engineering Development Proposal 306, Flight Test Evaluation of Light Undercoat Exterior Finishes.

AUTHOR: C. D. Crook:K DATE: 9-11-61 PAGE 1

I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

Since formulation of these epoxy organic coatings are given wide latitude, the principal properties are only known in-so-far as the epoxy coatings conform to the performance requirements of Boeing Material Specification 10-15.

A. Mechanical

1. Adhesion - excellent
2. Hardness - minimum pencil hardness of H
3. Gloss - minimum of 85
4. Weather Resistance - excellent
5. Humidity Resistance - excellent

I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

B. Thermophysical

1. Heat Resistance - maximum operational temperature is 350°F.

2. Low Temperature Resistance - minimum operational temperature is -65°F.

3. Thermal Shock - no loss of adhesion upon rapid cooling from 140°F. to -65°F.

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I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

V. **PRINCIPAL PROPERTIES:**

C. Electrical

Information no available due to lack of need for Boeing - Wichita investigating this property.

AUTHOR: C. D. Crook DATE: 9-11-61

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

V. **PRINCIPAL PROPERTIES:**

D. Chemical

1. Fluid Resistance - Resistant to water, MIL-H-5606A, MIL-L-7808 and MIL-S-3136 Type III.

2. Pot Life - minimum of 16 hours.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-solid High Polymers **CODE:** 7-8-6

II. **MATERIAL NAME:** Epoxy Organic Coatings

VI. **RECOMMENDED USES:**

Since epoxy organic coatings are more expensive than the usual type of organic coating, use is recommended only for protection against severe environments.

VII. **SUPPLIERS, AVAILABILITY AND COST:**

Cost of the primer and enamel is the same and is approximately $8.50 per mixed (base component plus catalyst) gallon.

Epoxy organic coatings conforming to Boeing Material Specification 10-15 are available from the following paint manufacturers:

1. Sherwin Williams
   Los Angeles, California

2. Andrew Brown
   Irving, Texas

3. W. P. Fuller Company
   Los Angeles, California

VIII. **REFERENCES:**

A. Boeing Materials Specification 10-15

B. Boeing Engineering Development Proposal 305, Flight Test Evaluation of Light Undercoat Exterior Finishes

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-9

II. **MATERIAL NAME:** Neoprene Organic Coating

III. **GENERAL DESCRIPTION:**

The neoprene coating described herein is controlled by MIL-C-27315 which specifies a primer and white rain erosion resistant coating of a solvent dispersed elastomeric type suitable for brush or spray application to plastic laminates. The purpose of the coating system is to protect aircraft and missile exterior plastic parts from rain erosion and thermal radiation.

IV. **DEVELOPMENT PROGRAM:**

Engineering Change Proposal 939 changed the rain erosion resistant coating for B-52 exterior plastic parts from the non-thermal reflective MIL-C-7439 coating to the thermal reflective MIL-C-27315 coating. The topcoat of the sole qualified source was unsatisfactory for spray application due to excessive viscosity reduction of the package material to eliminate cob-webbing. Preliminary work indicated that an entirely different type of thinner was required from that recommended by the manufacturer. Thus, it was necessary that an appropriate thinner be found and also that the performance of the system not be impaired as a result of deviating from the manufacturers recommended viscosity reduction procedure. This work was done under Boeing-Wichita Job Report F-2-189, Investigation of MIL-C-27315 Thermally Reflective Rain Erosion Resistant Coating.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-9

II. **MATERIAL NAME:** Neoprene Organic Coating

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

1. Adhesion - Excellent.
2. Water resistance - Excellent except for yellowing.
3. Weather resistance - Excellent except for yellowing.
4. Viscosity reduction - There is no known topcoat thinner that will provide both cobwebb elimination and adequate film build without sags. The most satisfactory known viscosity reduction procedure is a 1:4 up to 1:6 reduction of topcoat at package viscosity with methyl ethyl ketone. At this reduction approximately 125 coats are required to obtain a 10 mil coating free of sags.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-9

II. **MATERIAL NAME:** Neoprene Organic Coating

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

1. Thermal Shock Resistance - The coating system suffers no loss of adhesion upon rapid cooling from 140°F to -65°F.

I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-9

II. **MATERIAL NAME:** Neoprene Organic Coating

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information not available due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

V PRINCIPAL PROPERTIES:

D. Chemical

1. Aromatic Fuel Resistance - The coating system is resistant to aromatic fuel.

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I. **CATEGORY:** Liquid and Semi-Solid High Polymers **CODE:** 7-8-9

II. **MATERIAL NAME:** Neoprene Organic Coating

VI. **RECOMMENDED USE:**

None other than that specified by MIL-C-27315.

VII. **SUPPLIERS, AVAILABILITY AND COST:**

1. The supplier of the neoprene coating investigated by The Boeing Company is given below. This neoprene coating is currently available.

   Gates Engineering Company
   Wilmington 99, Delaware

   Gaco N-18 Primer (Red Color)
   Gaco N-83 White Neoprene Topcoat

2. Cost:

   a. Primer $14.00 per gallon.

   b. Topcoat $12.50 per gallon.

VIII. **REFERENCES:**

1. MIL-C-27315, Coating System, Elastomeric Thermally Reflective, Rain Erosion Resistant and Antistatic, For Aircraft and Missile Exterior Plastic Parts.

2. MIL-C-7439B, Coating System, Elastomeric, Rain Erosion Resistant and Rain Erosion Resistant with Anti-Static Treatment, for Exterior Aircraft and Missile Plastic Parts.

3. Boeing-Wichita Job Report F-2-189, Investigation of MIL-C-27315 Thermally Reflective Rain Erosion Resistant Coating.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

III. GENERAL DESCRIPTION:

The object of this program was to investigate methods to decrease the amount of lint entering the fuel system by controlling lint production of uniforms worn by personnel.

IV. DEVELOPMENTAL BACKGROUND:

It was found that lint accounted for a large amount of the fuel contamination in the B-52G. This program was initiated in an effort to determine the lint shedding characteristics of cotton and synthetic garments, and to determine means of decreasing the amount of lint produced by these garments.

AUTHOR: V. P. Kassions DATE: 9-13-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

A. Mechanical

The following materials tabulated in their order of lint suppression effectiveness:

Order	Trade Name	Chemical Name	Manufacturer	Strength of Solution	Method of Applying Material
A	Elvanol	Polyvinyl	Dupont	1% by Wt. Water	Test material immersed in solution
B	Revlon Hair Spray	Proprietary Cosmetic	Revlon, Inc., N.Y.	As Pkgd.	Material applied by spray from pressurized container
C	Methocel Partially Acetylated	Methyl-Cellulose	Dow Chem.	1% by Wt. by water	Test material immersed in solution

The supporting data is shown in Table I and II as well as shown in Figures 1, 2, 3 and 4.

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TEST SOLUTION	NEW MATERIAL Lint Weight Grams	USED MATERIAL Lint Weight Grams	COMMENTS New Material	COMMENTS Used Material
No Treatment	0.0208	0.0381	Average Value (Seven tests run for Standardization)	Average value (Two tests run for Standardization)
(Methycellulose) Methocel 1%	0.0260*	0.0154	Less lint, but small particles of sizing material increased total weight.	Lint decreased appreciably.
(Methycellulose Methocel 5%	0.3144	Not tested	Lint decreased - Material too stiff for personnel to wear.	Material would be too stiff for personnel to wear.
Polyox (WSR 301)	0.0332	0.0280	Heavy lint deposit, and particles of sizing material.	Slight weight decrease. Lint deposit heavy.
Starch (Linit) 1%	0.227	0.0571	Heavy lint deposit, and particles of sizing material.	Heavy lint deposit break-down of test piece, in some areas gave high lint weight.
(Polyvinyl Alcohol) Grade 50-42 Elvanol 1%	0.0102	0.0087	Lint decreased substantially. Material not excessively stiff.	Lint decreased substantially. Material not excessively stiff.
Revlon Hair Spray	0.0215*	0.0108	Lint decreased, small particles of sizing material present. Material not stiff.	Lint decreased, small particles of sizing material present. Material not stiff.
No treatment inside surface of Garment tested	0.0229	0.0222	Slightly greater linting tendency than wear surface.	Slightly less linting tendency, than wear surface.
Material washed once with soap and water	0.0357	Not Tested	Sizing removed, shows more lint than unwashed material.	Material not tested due to previous washings.

* The new material showed some inconsistencies due to removal of the sizing material during testing. The weight in cases shown was due to the presence of sizing material on the filter, and not entirely to the lint deposit. The used material data show a more reliable indication as to results to be expected from use of the lint suppressing materials.

TABLE I

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabric for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

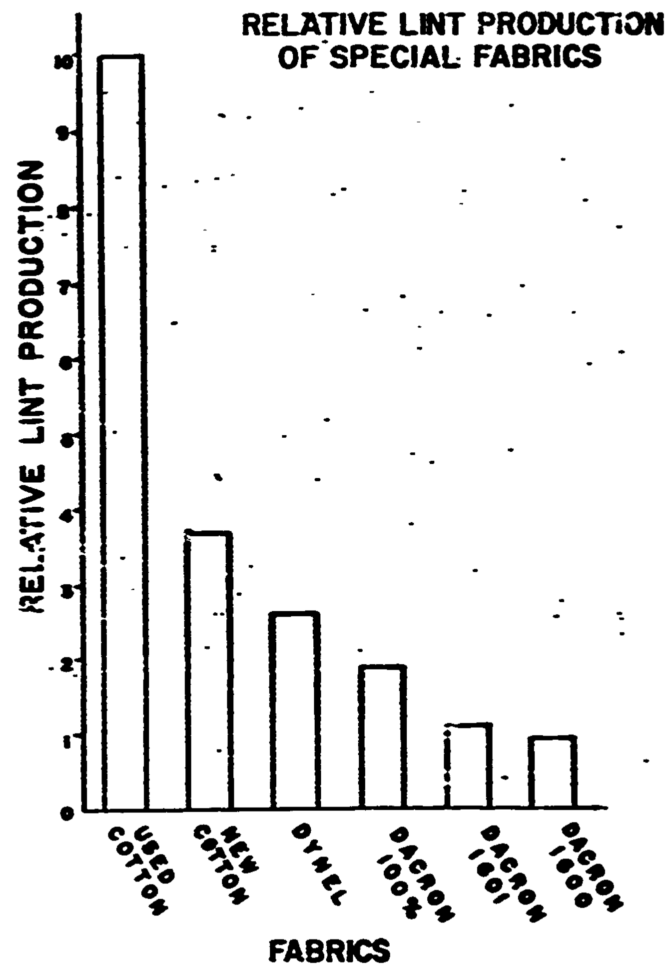

FIGURE 1

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-6-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

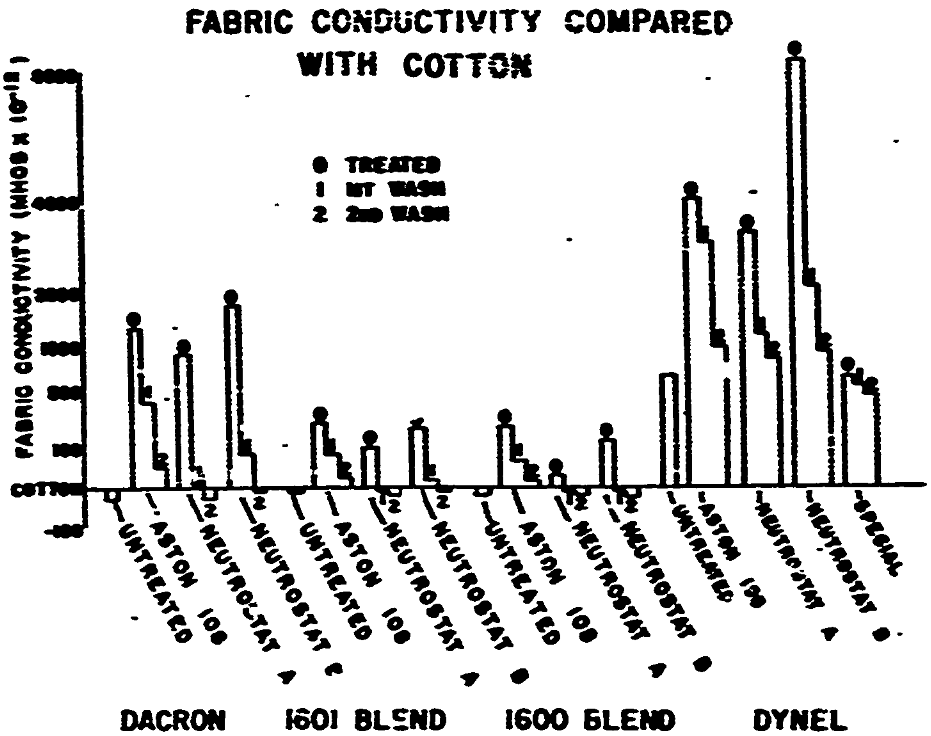

FIGURE 2

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I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

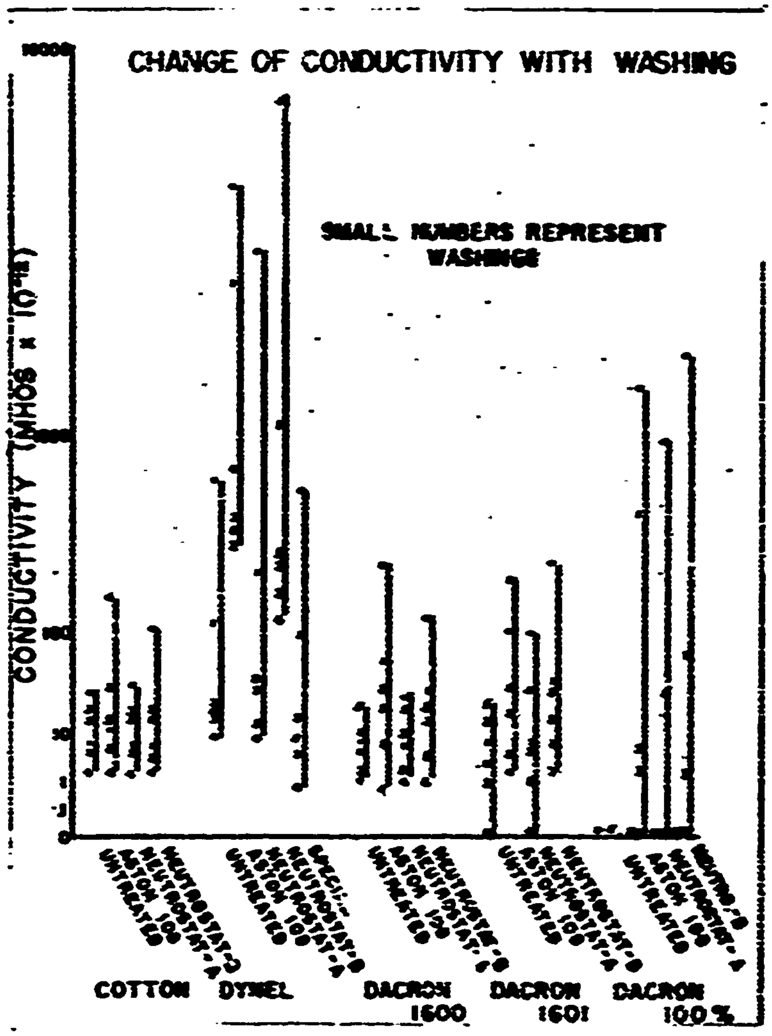

FIGURE 3

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

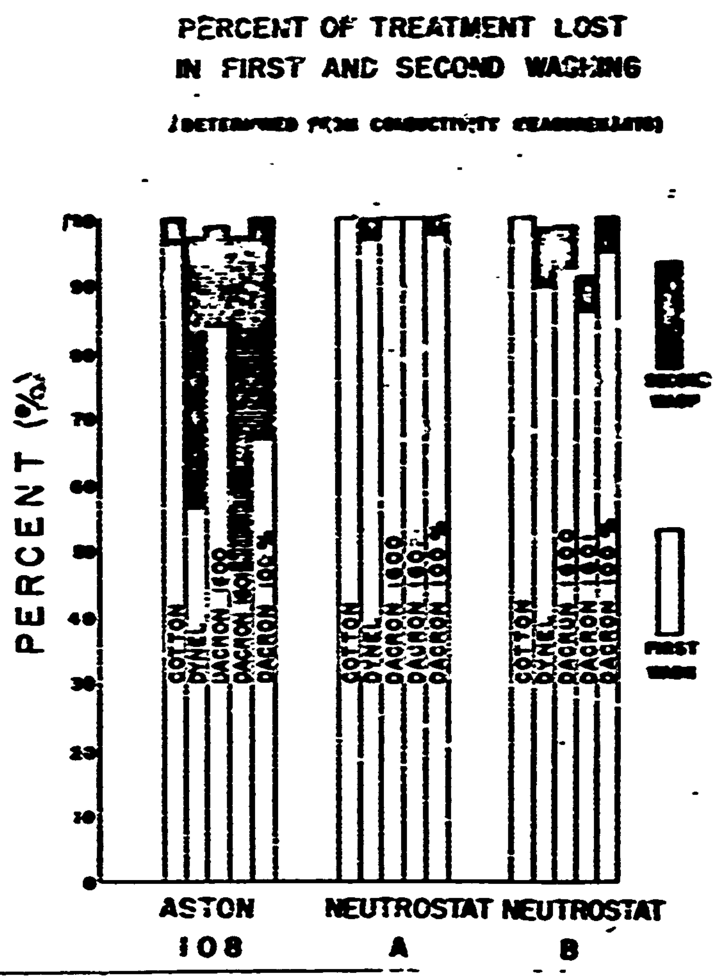

FIGURE 4

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I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

The strength of the material was determined for each sample and is recorded as follows

SAMPLE NUMBER	STRENGTH LBS	REMARKS
1 (F)*	202	Standard Sample
2 (F)	289	Standard Sample
3 (F)	268	Standard Sample
10 (W)*	297	Standard Sample
17 (W)	312	Standard Sample
21 (W)	365	Standard Sample
14 (F)	240	4 days in BMS 3-2, Type I
15 (F)	289	4 days in BMS 11-7
16 (F)	223	4 days in methyl ethyl ketone
22 (W)	300	4 days in BMS 3-2, Type I
23 (W)	300	4 days in BMS 11-7
24 (W)	300	4 days in methyl ethyl ketone
25 (F)	228	8 days in BMS 3-2, Type I
26 (F)	228	8 days in BMS 11-7
27 (F)	220	8 days in methyl ethyl ketone
28 (W)	287	8 days in BMS 3-2, Type I
29 (W)	231	8 days in BMS 11-7
30 (W)	240	8 days in methyl ethyl ketone

* (F) Fill Direction (W) Warp Direction.

Test results indicate that no change in strength or weight of dacron blend fiber samples could be related to the samples being subjected to BMS 3-2,(Type I), BMS 11-7 and methyl ethyl ketone for a period of 8 days. The Quality Control Laboratory is not equipped to differentiate between dacron blends and therefore cannot analyze the material to identify fabric composition.

TABLE II

AUTHOR: V. P. Hassions DATE: 9-13-61 **PAGE 8.**

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's investigation of this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's investigation of this property.

AUTHOR: V. P. Massions DATE: 9-13-61 PAGE 10.

MATERIALS & PROCESS UNIT

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information not available due to lack of need for Boeing-Wichita's investigation of this property.

I. **CATEGORY:** Fibrous and Filamentary Materials **CODE:** 8-8-0

II. **MATERIAL NAME:** Investigation of Fabrics for Lint-Free Condition

VI. **RECOMMENDED USES:**

Elvanol, Grade 50-42, recommended for addition to cotton protective clothing, the strength of the solution being one percent by weight in water, applied by immersion in the solution. It was further recommended that when new uniforms are ordered, that the cotton overalls be replaced by synthetic dacron blend #1600 fabrics. This recommendation is supported by Table II and Figures 1, 2, 3, and 4.

VII. **SUPPLIERS AND TRADE NAMES:**

Dacron 1600 Fabrics from Worklon, Inc.
253 West 28th Street
New York 1, New York

Dacron Blend #1600 - H.P. Ogden Co.
Empire State Building
New York, New York

"Neutrostat B"
The Simco Company
Lansdale, Pennsylvania

Polyvinyl Alcohol
Elvanol Grade 50-42
E. I. duPont deNemours Co.

VIII. **REFERENCES:**

A. Boeing-Wichita Manufacturing Research Report 67.5, "Lintless Fabric Clothing vs Present Protective Clothing, Comparative Evaluation."

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials

CODE: 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

III. **GENERAL DESCRIPTION:**

The objective of this program was to prepare and apply combinations of ceramic adhesives and brazing alloys for metal to metal bonding suitable for use at elevated temperatures.

IV. **DEVELOPMENT BACKGROUND:**

The high temperature use of ceramic materials for various applications makes ceramic adhesives a logical method of bonding structures subjected to service temperatures in excess of the 400°F. maximum use temperature of organic adhesives.

Unfortunately, the strength and ductility of existing ceramic adhesives are not comparable with the competitive method of bonding which is brazing.

A disadvantage in the use of brazing lies in the fact that protective atmosphere must be used to prevent the metal from oxidizing.

It was proposed that brazing alloys be combined with ceramic adhesives. It was felt that the ceramic adhesive would prevent oxidation of the base metal, and the bonding characteristics of the adhesive coupled with the bonding ability and ductility of the braze material would produce a bond, when fired in air, which would be superior to the ceramic adhesives reported in the literature.

AUTHOR: J. B. Whitney DATE: 9-11-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

III. **PRINCIPAL PROPERTIES:**

A. Mechanical

1. Room temperature lap shear strengths of ceramic adhesive-Silvaloy 345 Pd after 100 hours exposure to salt spray test (MIL-STD-202B, Method 101A)

Standard (No Salt Spray Exposure)		100 Hours Salt Spray	
Specimen	Room Temp. Lap Shear Strength (psi)	Specimen	Room Temp. Lap Shear Strength (psi)
1	24,300	1	24,342
2	23,125	2	25,107
3	29,166	3	24,000
Average	25,530	Average	24,916

2. See Section B for additional mechanical properties.

AUTHOR: J. B. Whitney DATE: 9-11-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials . **CODE:** 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

Elevated temperature lap shear strengths of A-286 alloy bonded with ceramic adhesive-Silvaloy Pd 845 brazing alloy combination.

Temp. (°F.)	Sample	Lap Shear Strength (psi)
Room	1	24,000
	2	25,470
	3	25,289
	Average	25,379
250	1	20,413
	2	21,750
	3	2[illegible],3[illegible]8
	Average	22,910
500	1	14,[illegible]75
	2	22,812
	3	13,500
	Average	16,996
750	1	9,718
	2	8,147
	3	
	Average	8,932
1000	1	5,026
	2	5,350
	3	
	Average	5,188

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing - Wichita's investigating this property.

I. **CATEGORY:** Composite Materials **CODE:** 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

V. PRINCIPAL PROPERTIES:

D. Chemical

1. Ceramic Adhesive Composition

a. Frit Raw Batch Composition

Powdered Quartz	68
Sodium Nitrate	6
Sodium Carbonate	17
Calcium Carbonate	27
Boric Acid	185
Sodium Silico Fluoride	5

Smelted at 2300°F.

b. Mill Addition

Frit	100
Molybdenum Oxide	3/4
Chrome Oxide	4
Water	140

2. Brazing Alloy Composition

	(1)	(2)
Silver	92.5	84.5
Copper	7.3	7.4
Lithium	0.2	0.2
Palladium		2.4
Indium		5.5

I. **CATEGORY:** Composite Materials **CODE:** 9-2-1

II. **MATERIAL NAME:** Ceramic Braze

VI. **RECOMMENDED USES:**

This method of bonding would be used for honeycomb sandwich lap bonded structures, and other metal joining problems where structural adhesives or brazing would be suitable. The present state of the research on this project does not make it ready for release as a pilot plant or production process.

VII. **SUPPLIERS AND TRADE NAMES:**

A. Brazing Alloys

1. Silver-Base Alloys

Handy and Harmon
80-84 Fulton Street
New York 38, New York
"Lithobraze 925"

Engelhard Industries, Inc.
231 New Jersey R.R. Ave.
Newark, New Jersey
"Silvaloy Pd 845"
"Silvaloy AE 100"

B. Availability

Silver-base alloys available as foil, strip and powder. Ceramic adhesives would have to be smelted in own laboratory or by porcelain enamel frit manufacturers.

VIII. **REFERENCES:**

1. BAC Document D3-3026 "Ceramic Adhesive Systems"

2. BAC Document D3-3746 "Ceramic Adhesive Systems"

AUTHOR: J. B. Whitney DATE: 9-11-61 PAGE -

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Composite Material CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

III. GENERAL DESCRIPTION:

The data presented herein covers some fatigue properties of Epon 828 - Tonox, Style 143V glass fabric laminates.

IV. DEVELOPMENTAL BACKGROUND:

The fatigue data was developed specifically for application to design of a 1/2 scale model. The scale model was designed with all plastic construction to duplicate deflections of a full-size all metal design.

AUTHOR: J. Elton 14 August 1961 PAGE 1

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

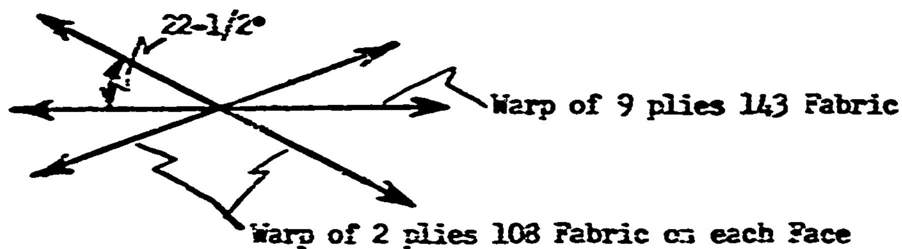
II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

V. **PRINCIPAL PROPERTIES:**

A. Mechanical Properties - Fatigue

Laminate Preparation

All laminates were prepared by vacuum bag void-free techniques and post-cured three hours at 400°F. Resin composition was 26.5 parts by weight of Tonox to 100 parts Epon 828 by weight. Each laminate consisted of nine plies of parallel laminated 143V glass fabric and two plies of 108 glass fabric on each face. The 108 glass fabric was laid up as shown below:



Test Procedures

Static physical strengths were determined per LP-406b. Fatigue specimens were tested in Sonntag SF-10U fatigue machines. Photographs BWA-14566 and BWA-14567 show views of the test set-up. The first fatigue specimen (No. 1) had a test section width of 2.00 inches and a grip section width of 5.0 inches while the second specimen (No. 2) had a grip width of 3.5 inches. A two inch radius was used for transition from the test section to grip section. These specimens are shown in photograph BWA-19762. The remaining specimens contained an elliptical test section having a minimum width of 1.0 inch and a grip section width of 1.98 inches. These specimens are shown in photographs BWA-14429 and BWA-19763. Maximum stress levels used in conducting the tests ranged from 30,850 psi to 55,500 psi with a maximum to minimum stress ratio of 0.62.

AUTHOR: J. Elton JE 14 August 1961 PAGE 2

I. CATEGORY: Composite Material CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical Properties (continued)

Test Results

Specimens number 1 and number 2 failed in shear beginning in the radius and extending into the end fitting. These failures are shown in photograph BWA-19762.

Failure of the elliptical test specimens appeared to begin as tensile failure in the test section and then progress as shear into the end section. These failures are shown in photographs BWA-14429 and BWA-19763.

Failures varied from 1000 cycles at a maximum stress level of 55,500 psi to no failure after 50,000,000 cycles at a maximum stress level of 30,850 psi.

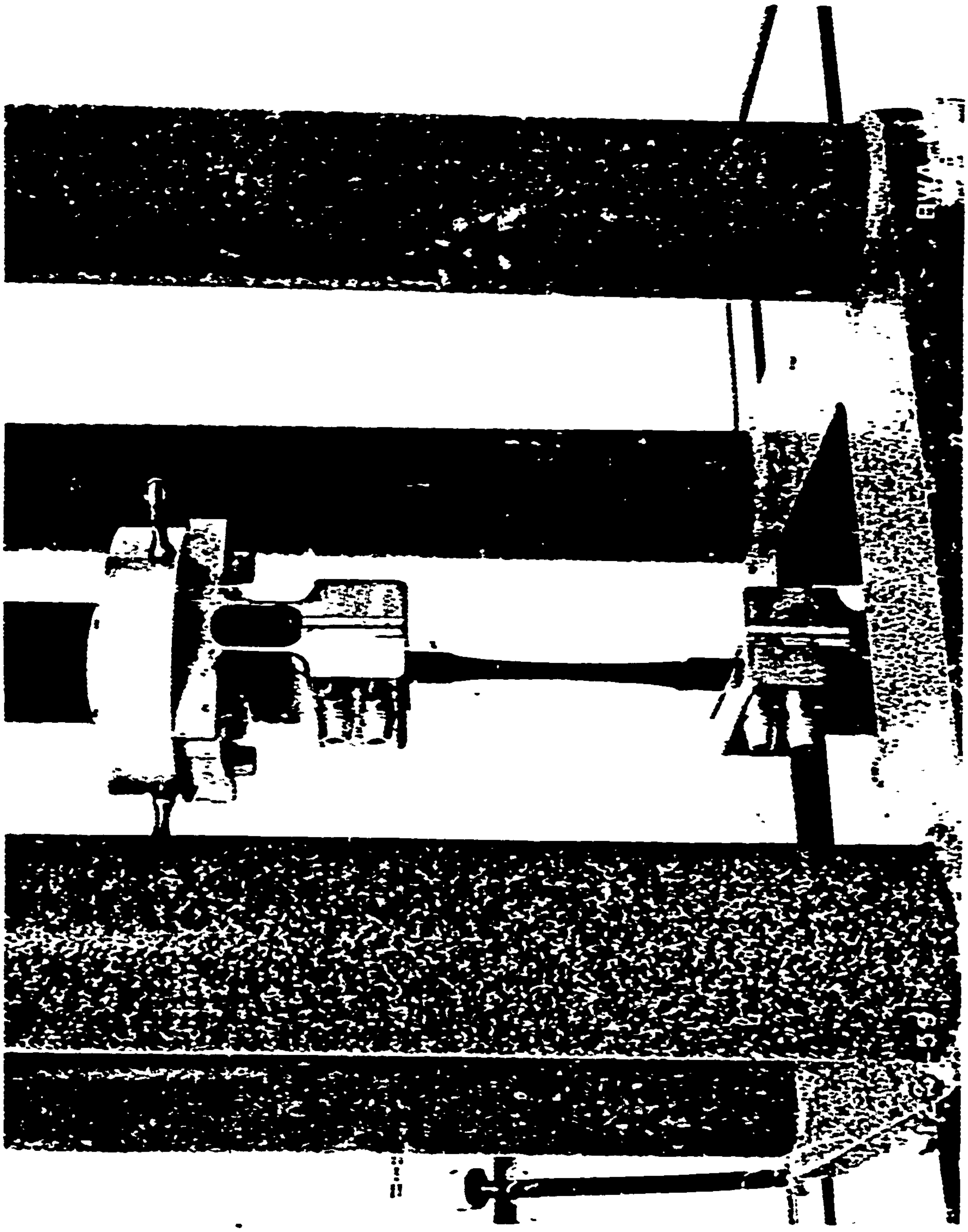
All data is presented in figures 1 through 5.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates



HWA-14566

AUTHOR: J. Hilton

14 August 1961

MATERIALS & PROCESS UNIT

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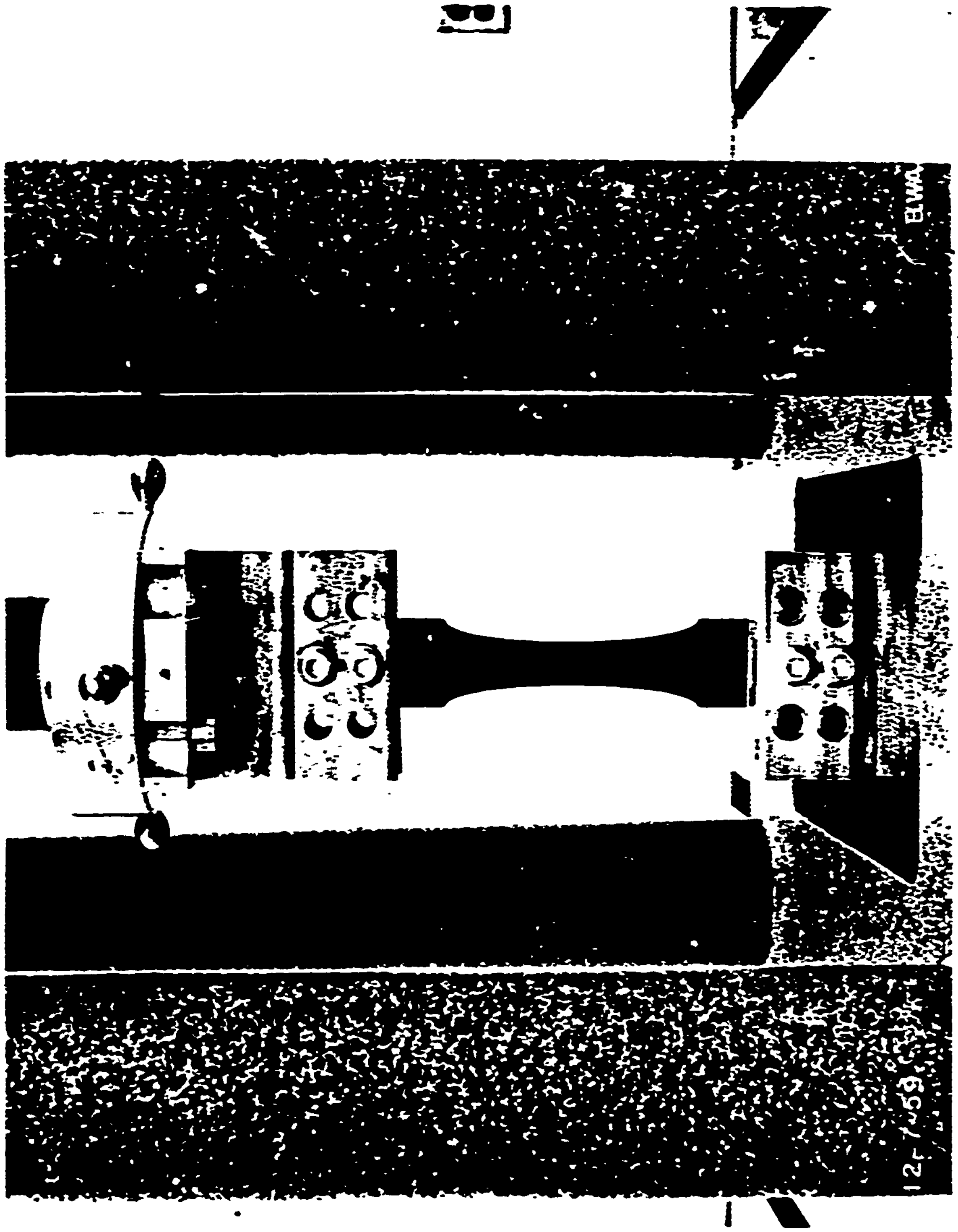
BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material   **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton JE

BWA -14597
14 August 1961

MATERIALS & PROCESS UNIT

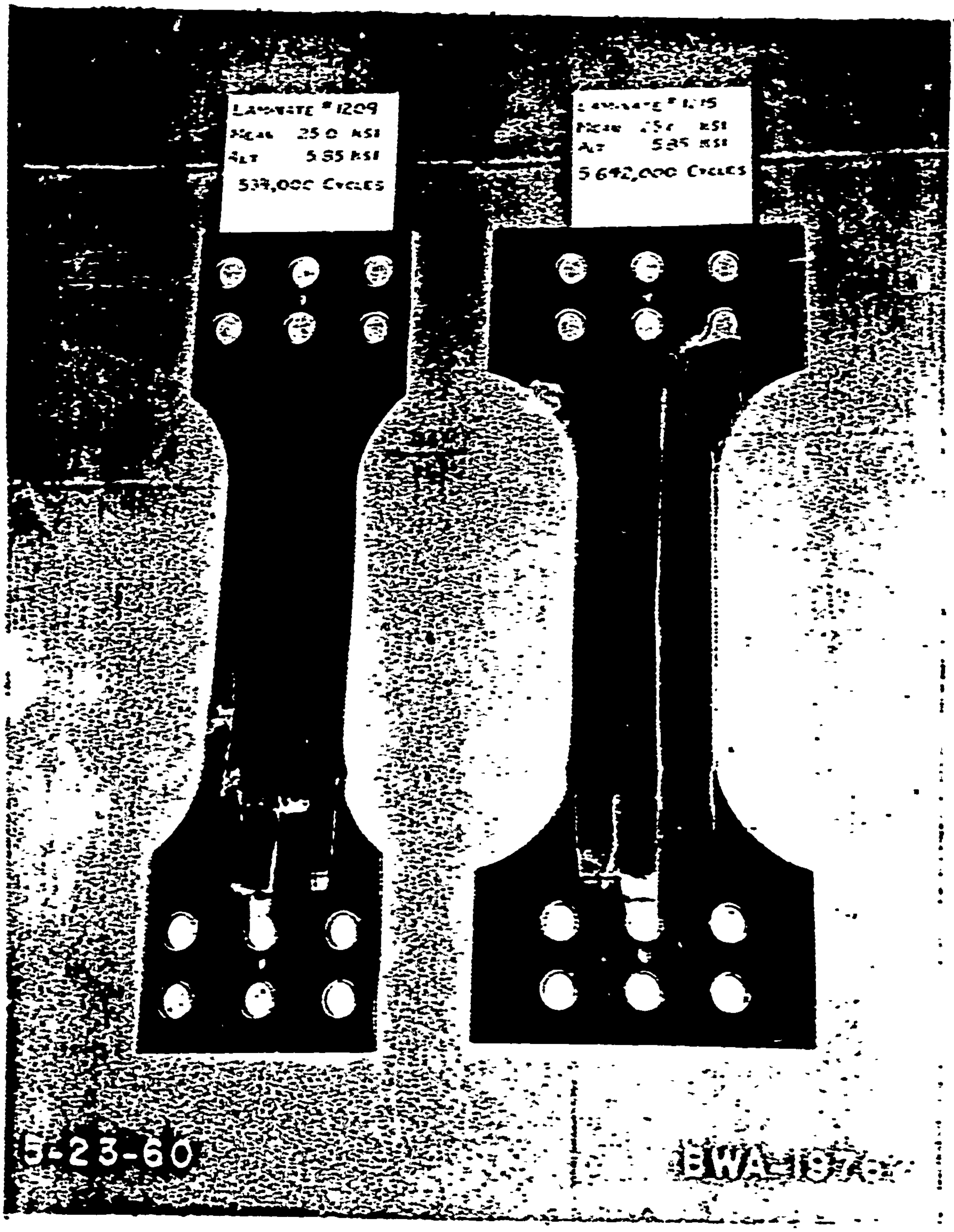
.76

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material CODE: 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton JE

BWA-19762
14 August 1961

MATERIALS & PROCESS UNIT

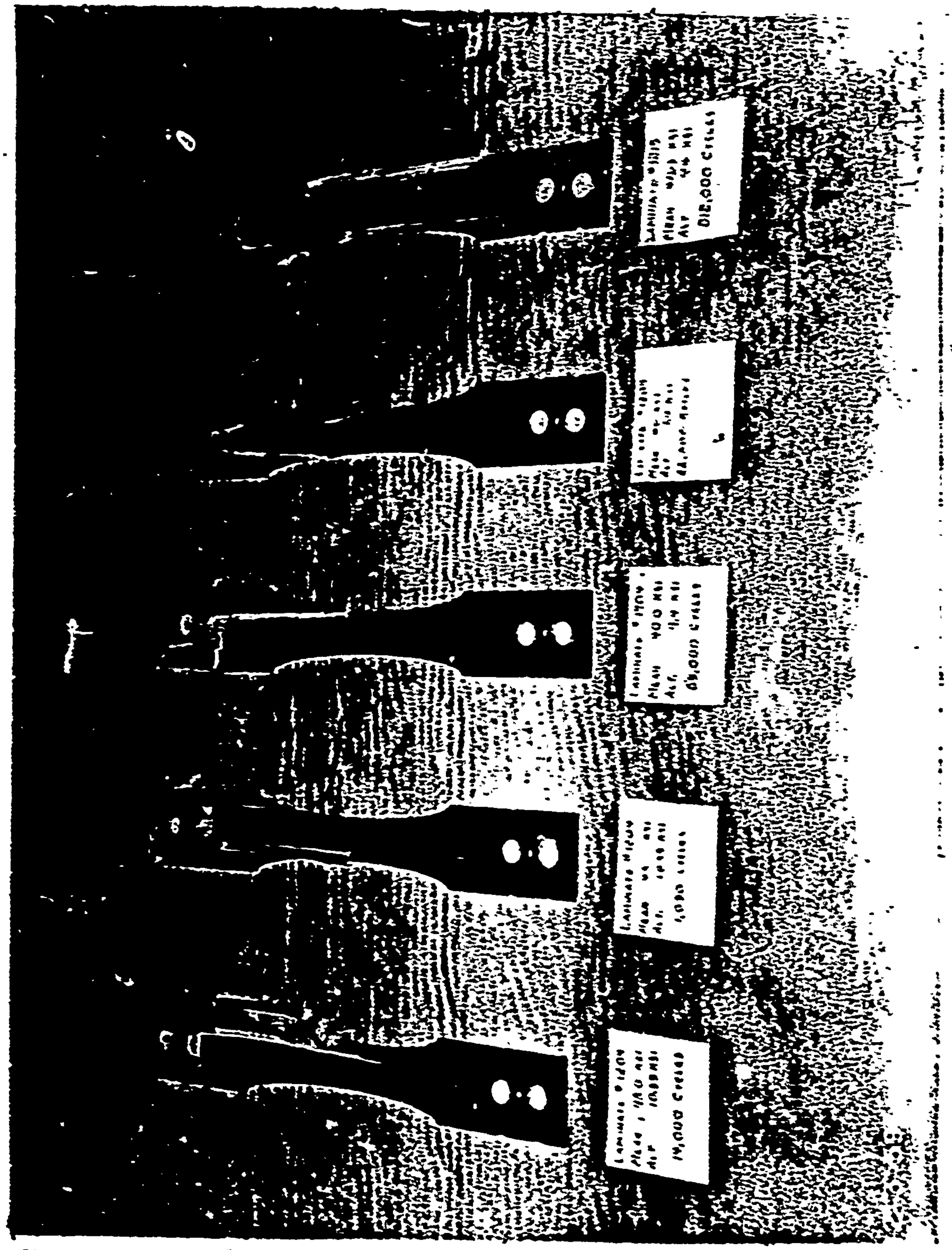
277

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

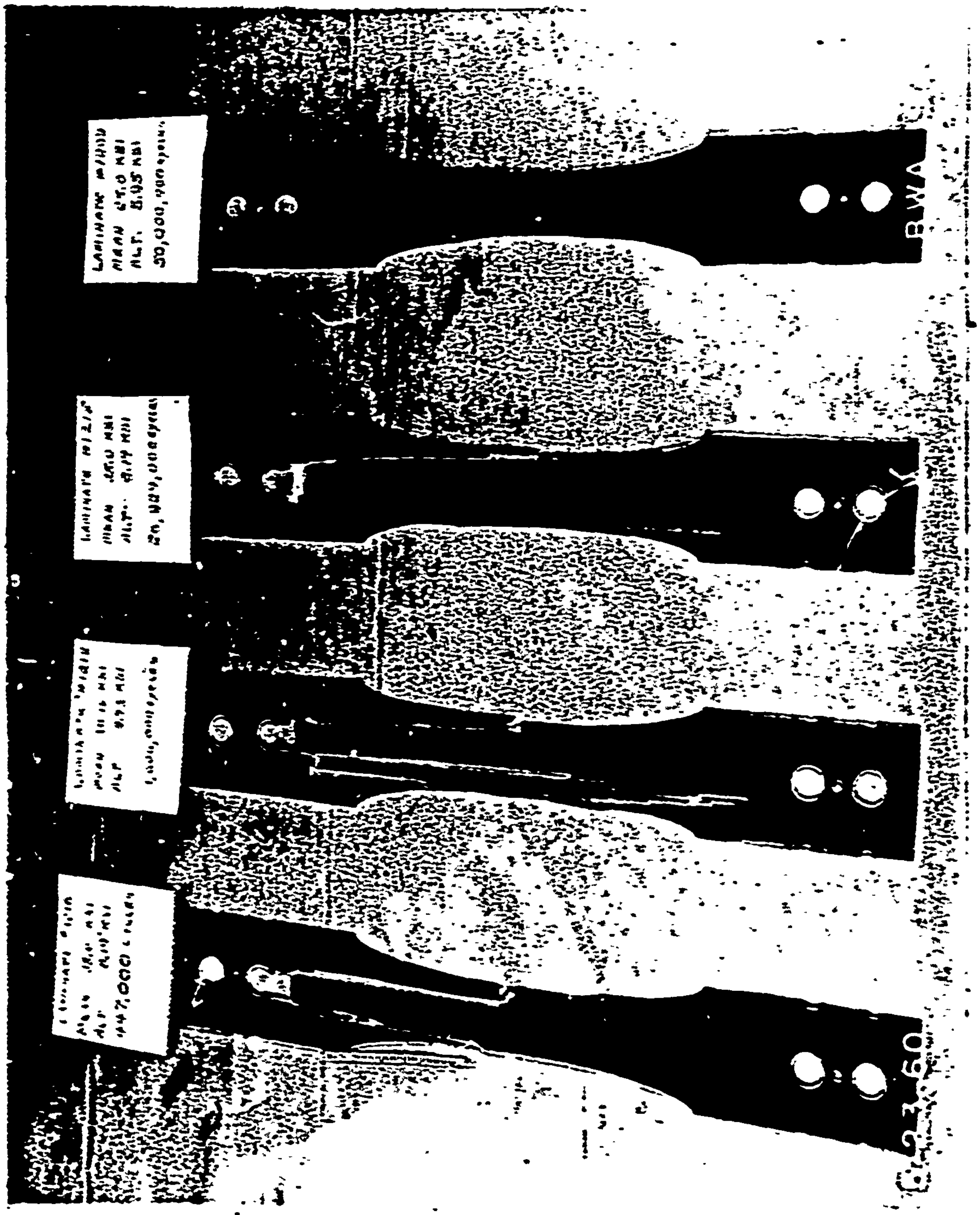
II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton JE BWA-1429 PAGE 7
14 August 1961

I. CATEGORY: Composite Material CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

SPECIMEN NUMBER	LAMINATE NUMBER	WIDTH INCHES	THICKNESS INCHES	STRESS LEVEL PSI	NUMBER OF CYCLES TO FAILURE	TYPE OF FAILURE
1	1215	2.00	.074	25,000 ± 5,850	5,612,000	Shear
2	1209	2.00	.078	25,000 ± 5,850	534,000	Shear
3	1209	0.98	.077	25,000 ± 5,850	50,000,000	No Failure
4	1215	1.14	.075	35,000 ± 8,190	26,829,000	▷
5	1216	1.15	.080	35,000 ± 8,190	447,000	
6	1215	1.14	.074	38,150 ± 8,930	3,606,000	
7	1215	1.16	.074	40,000 ± 9,400	812,000	
8	1209	1.16	.076	40,000 ± 9,400	22,000	
9	1204	1.16	.088	40,000 ± 9,400	65,000	
10	1204	1.15	.086	45,000 ± 10,550	1,000	
11	1204	1.15	.090	45,000 ± 10,550	14,000	▷

▷ Initial failure was tensile and then progressed as shear into the end fitting section.

FIGURE 1

AUTHOR: J. Elton JE 14 August 1961

720

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

Panel No. 1376
Resin
Fabric & Finish
No. of Plies
Mfgr.

Specimen Drawing No.
Test Machine
Rate of Loading

1 → Test At Room Temperature
2 → Boil 2 Hrs in Distilled H_2O, Test at R.T.

SPEC. NO.	TEST CONDITION	LOAD DIRECTION	WIDTH (W)	THICKNESS (T)	AREA (A)	GAUGE LENGTH (G)	ULTIMATE LOAD (P)	TENSILE STRENGTH (S)	INITIAL P/δ	INITIAL MOD. OF ELAS. (E_T) (10^6 PSI)	S AVG.	S STD. DEV.	E_T AVG.	E_T STD. DEV.		
1	1	0°	0.248	0.088	.0218	2.0	1805	86400	2600/.05	5.00						
2			.248	.085	.0211		1811	86000	2390/.05	4.82						
3			.247	.086	.0217		1730	81600	2390/.05	4.43						
4			.247	.086	.0211		1755	84100	2240/.05	4.33						
5			.248	.086	.0213		1820	86,800	2390/.05	4.47	85,400			4.59		
6	2		.246	.086	.0212		1810	85400	1225/.025	5.00						
7			.245	.086	.0211		1740	81200	1060/.025	4.82						
8			.246	.086	.0212		1825	86400	1236/.025	4.72						
9			.244	.086	.0210		1815	87,400	1237/.025	4.67						
10	2	0°	.245	.085	.0211	2.0	1760	81,600	1225/.025	4.70	86,300			4.66		

W = Width of reduced section, inches
T = Thickness of specimen, inches
A = Gross section area, inches²
P = Ultimate load, lbs.
S = Tensile Strength, psi
G = Gauge length, inches

$S = \frac{P}{A}$

$E_T = \frac{P}{\delta}\cdot\frac{G}{A}$

$\frac{P}{\delta}$ = Slope of straight line portion of load - deformation curve, lbs./in.

AUTHOR: J. Elton JE

FIGURE 2
14 August 1961

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

Panel No. 7276
Resin
Fabric & Finish
No. of Plies
Mfgr.

Reference
Specimen Drawing No.
Test Machine
Rate of Loading

[1] → Test at Room Temperature
[2] → Boil 2 hrs in Distilled H_2O, Test at R.T.

SPEC. NO.	TEST CONDITION	WARP ORIENTATION	WIDTH (W)	THICKNESS (T)	AREA (A)	ULTIMATE COMPRESSION LOAD (P)	EDGEWISE COMPRESSIVE STRENGTH (S)	INITIAL (P/Y)	INITIAL MOD. OF COMP. (E_c) (10^6 PSI)	S AVG.	S STD. DEV.	E_c AVG.	E_c STD. DEV.
1	[1]	0°	0.503	0.081	.0417	2920	70100	[illegible]	5.48				
2			.503	.082	.0413	2810	68200	[illegible]	5.61				
3			.502	.082	.0413	2770	67200	[illegible]	5.60				
4			.503	.082	.0412	2700	65500	[illegible]	[illegible]				
5	[1]		.503	.082	.0413	2925	70300	[illegible]	5.46	69100		5.47	
6	[2]		.503	.083	.0417	2350	56900	[illegible]	5.24				
7			.503	.083	.0417	2580	61900	[illegible]	5.40				
8			.503	.083	.0417	2580	61900	[illegible]	5.36				
9			.503	.083	.0418	2665	63900	[illegible]	5.04				
10	[2]	0°	.503	.082	.0413	2485	60500	[illegible]	5.13	60800		5.23	

W = Width of Specimen, inches
T = Thickness of Specimen, inches
A = Cross Section Area, (inches)²
P = Ultimate load, lbs.
S = Edgewise Compressive Strength, psi
G = Gauge Length, inches

$S = \frac{P}{A}$

$E_c = \frac{P}{Y}\frac{G}{A}$

$\frac{P}{Y}$ = Slope of straight line portion of load - deformation curve, lbs./in.

FIGURE 3

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

Panel No. 1216
Resin
Fabric & Finish
No. of Plies
Vac.

Reference
Specimen Drawing No.
Test Machine
Rate of Loading

A — Test At Room Temperature
B — Boil 2 Hr. in Distilled H_2O, Test at R.T.

SPEC. NO.	TEST CONDITION	LAMP DIRECTION	WIDTH (b)	DEPTH (d)	DISTANCE BETWEEN SUPPORTS (L)	SPAN DEPTH RATIO	ULTIMATE LOAD (P)	FLEXURAL STRENGTH (S)	INITIAL (P/Y)	INITIAL MOD. OF ELAS. (10^6 PSI) E_B	AVG.	STD. DEV.	AVG.	STD. DEV.
1	A	0°	0.503	.083	1.5"	18.1	207	135,000	115/.08	4.34				
2			0.502	.083		18.1	200	130,000	111/.00	4.30				
3			0.503	.083		18.1	203	132,000	115/.08	4.32				
4			0.502	.083		18.1	206	134,000	114/.08	4.36				
5	A		0.502	.083		18.1	200	130,000	114/.08	4.26	132,000		4.25	
6	B		0.502	.086		17.4	186	118,000	118/.08	4.02				
7			0.503	.086		17.4	192	117,000	123/.08	4.13				
8			0.501	.086		17.4	181	116,000	124/.08	4.10				
9			0.502	.086		17.4	187	118,000	121/.08	4.00				
10	B	0°	0.502	.086	1.5"	17.4	197	118,000	121/.08	4.00	117,000		4.06	

$S = \frac{3PL}{2bd^2}$

S = Flexural stress, psi
P = Ultimate load, lbs.
L = Distance between supports, inches
b = Width of beam, inches
d = Depth of beam, inches

$E_B = \frac{L^3}{4bd^3}\left(\frac{P}{Y}\right)$

E_B = Modulus of elasticity in bending, psi
L = Distance between supports, inches
b = Width of beam, inches
d = Depth of beam, inches
$\left(\frac{P}{Y}\right)$ = Slope of straight line portion of load-deflection curve, lbs./inch

FIGURE 4

AUTHOR: J. Elton JE

14 August 1961

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

RESIN CONTENT

Laminate No.	Spec. No.	Cru. No.	Cru.+ Spec. (g)	Cru. Wt. (g)	Spec. Wt. (g)	Ignited Cru. + Spec. (g)	Loss of Wt. (g)	Thickness (inches)	% Resin	Avg. Resin Co. (%)
1216	1	117	19.2028	16.6300	2.5728	18.4726	0.7302	0.820	28.4	
	2	123	19.5832	16.9716	2.6116	18.8313	0.7519	0.830	28.8	
	3	125	19.0160	16.3515	2.6645	18.1806	0.8354	0.860	31.7	29.6

BARCOL HARDNESS

Laminate	1216	
Barcol Hardness	75	
	69	
	69	
	69	
	73	
	73	
	73	
	73	
	75	
	75	
Average Barcol Hardness	72	

FIGURE 5
14 August 1961

AUTHOR: J. Elton JE

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical:

Information not available due to lack of need for Boeing-Wichita investigating this property.

I. CATEGORY: Composite Material CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES:

C. Electrical:

Information not available due to lack of need for Boeing-Wichita investigating this property.

I. **CATEGORY:** Composite Material **CODE:** 9-7-1

II. **MATERIAL NAME:** Epon 828 and 143 Glass Fabric Laminates

V. **PRINCIPAL PROPERTIES:**

D. Chemical:

Information not available due to lack of need for Boeing-Wichita investigating this property.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Composite Material   CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

VI. RECOMMENDED USES:

1. Applications requiring the properties of this material.

VII. SUPPLIERS AND TRADE NAMES:

1. Epon 828, Shell Chemical Corporation.

2. Tonox, Naugatuck Chemical Company

VIII. REFERENCES:

1. Boeing-Wichita Job Report No. AP-1-18; Determination of The Fatigue Properties of Epon 828 Reinforced With 143 Glass Fabric.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan and 181-A-1100 Silane Finish Fabric

III. **GENERAL DESCRIPTION:**

The objective of this program was to determine the feasibility of using A-1100 silane finish fabric with epoxy resins.

IV. **DEVELOPMENTAL BACKGROUND:**

A variety of fabric finishes are available for glass cloth laminates. The proper finish must be selected to use with the correct resin to obtain the maximum properties from the finished product. Most fabric finishes falls into three categories, heat cleaned, chrome finished and Silane finished.

Volan A, a chrome finish fabric is the most universally used with epoxies and polyesters. A-1100, a Silane finish recently developed for use with epoxies and phenolics, has been reported to yield Mechanical Properties equal to the ones obtained with Volan finished fabric when used with epoxy resins.

Commercial literature released by leading glass fabric manufacturers, state that the wet retention strength of laminates using A-1100 is superior to other finishes because of the better wetability of the fabric. (This was found to be untrue).

It was felt that an evaluation of the Silane finished fabric was needed to verify the data released by commercial sources. Therefore, this job was initiated.

AUTHOR: E. Lofton DATE: 9-11-61 PAGE 1.

MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Laminate No.	1298	1299	1302	1303
% Resin Content	25.2	27.5	33.3	27.9
Finish of Fabric	181 Volan A	181 Volan A	A-1100 Silane	A-1100 Silane
Direction of Fabric Layup	Parallel Nested	Isotropic 45°	Isotropic 45°	Parallel Nested
Av. Flexural Strength at R.T. PSI	115,200	78,200	55,300	81,300
Av. Flexural Modulus at R.T. PSI	$4.65x10^6$	$3.76x10^6$	$2.98x10^6$	$3.95x10^6$
Av. Flexural Strength at R.T. After Being Conditioned for 30 Minutes at 180°F PSI	111,700	74,800	58,100	84,900
Av. Flexural Modulus at R.T. After being Conditioned for 30 minutes at 180°F PSI	$4.57x10^6$	$3.70x10^6$	$2.96x10^6$	$3.97x10^6$
Av. Flexural Strength at R.T. after 2 Hr. Boil in distilled water, PSI	107,700	73,600	55,000	82,900
Av. Flexural Modulus at R.T. after a 2 Hr boil in Distilled Water PSI	$4.63x10^6$	$3.34x10^6$	$3.00x10^6$	$3.77x10^6$

AUTHOR: E. Lofton DATE: 9-11-61 PAGE 2.

MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. **PRINCIPAL PROPERTIES:**

A. Mechanical (continued)

	1298	1299	1302	1303
Av. Flexural Strength at R.T. after being Conditioned for 192 Hrs. at 350°F PSI	149,900	70,600	65,000	89,300
Av. Flexural Modulus at R.T. after being Conditioned for 192 Hrs. at 350°F. PSI	$4.63x10^6$	$3.34x10^6$	$3.21x10^6$	$4.16x10^6$
Av. Tensile Strength at R.T. PSI	73,300	44,300	39,600	59,700
Av. Tensile Modulus at R.T. PSI	$4.63x10^6$	$3.47x10^6$	$2.82x10^6$	$3.92x10^6$
Av. Tensile Strength at R.T. After a 2 Hr. Boil in Distilled Water PSI	72,400	48,800	39,300	62,000
Av. Tensile Modulus at R.T. After a 2 Hr. Boil in Distilled Water PSI	$4.51x10^6$	$3.57x10^6$	$2.55x10^6$	$3.86x10^6$
Av. Tensile Strength at R.T. After Being Conditioned for 30 minutes at 180°F. PSI	72,100	47,000	40,300	61,800

AUTHOR: E. Lofton DATE: 9-11-61

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

	1298	1299	1302	1303
Av. Tensile Modulus at R.T. After being Conditioned for 30 minutes at 180°F PSI	$4.77x10^6$	$3.50x10^6$	$2.81x10^6$	$3.99x10^6$
Av. Edgewise Compressive Strength at R. T. PSI	68,900	52,600	46,300	61,500
Av. Edgewise Compressive Modulus at R. T. PSI	$5.06x10^6$	$4.15x10^6$	$3.16x10^6$	$4.40x10^6$
Av. Edgewise Compressive Strength at R.T. After a 2 Hr Boil in Distilled Water, PSI	[illegible]	52,900	49,300	62,500
Av. Edgewise Compressive Modulus After a 2 Hr. Boil in Distilled Water, PSI	$5.[illegible]3x10^6$	$4.09x10^6$	$2.93x10^6$	$4.33x10^6$
Av. Edgewise Compressive Strength at R.T. After 192 Hrs. of Conditioning at 350°F., PSI	65,[illegible]00	51,600	53,200	66,700
Av. Edgewise Compressive Modulus at R.T. After 192 Hrs. of Conditioning at 350°F., PSI	$4.81x10^6$	$3.63x10^6$	$3.18x10^6$	$4.27x10^6$

E. L.

AUTHOR: E. Lofton DATE: 9-11-61

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials   **CODE:** 9-7-1

II. **MATERIAL NAME:** 181Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

B. Thermophysical

	1298	1299	1302	1303
Av. Flexural Strength at 250°F After Being Conditioned for 192 Hrs. at 350°F, PSI	93,900	65,600	56,000	76,300
Av. Flexural Modulus at 250°F. After Being Conditioned for 192 Hrs. at 350°F, PSI	$4.16x10^6$	$3.02x10^6$	$2.86x10^6$	$3.76x10^6$
Av. Flexural Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F., PSI	60,000	46,300	47,000	65,400
Av. Flexural Modulus at 350°F After Being Conditioned for 192 Hrs. at 350°F, PSI	$3.64x10^6$	$2.58x10^6$	$2.50x10^6$	$3.54x10^6$
Av. Edgewise Compressive Strength at 180°F After 30 Min. of Conditioning at 180°F, PSI	65,000	52,200	46,300	61,500
Av. Edgewise Compressive Modulus at 180°F After 30 Min. of Conditioning at 180°F, PSI	$3.43x10^6$	$2.58x10^6$	$2.05x10^6$	$3.00x10^6$
Av. Edgewise Compressive Strength at 250°F After Being Conditioned for 192 Hrs. at 350°F, PSI	57,000	39,000	43,000	59,400

AUTHOR: E. Lofton   DATE: 9-11-61   PAGE 5.

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES: (Continued)

B. Thermophysical (continued)

	1298	1298	1302	1303
Av. Edgewise Compressive Modulus at 250°F After Being Conditioned for 192 Hrs. at 350°F, PSI	3.34×10^6	2.51×10^6	2.10×10^6	3.04×10^6
Av. Edgewise Compressive Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F, PSI	46,600	33,400	32,000	45,600
Av. Edgewise Compressive Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F., PSI	3.08×10^6	2.13×10^6	1.85×10^6	2.67×10^6

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

E. L

AUTHOR: E. Lofton DATE: 9-11-61 PAGE 8.

MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-1

II. **MATERIAL NAME:** 181 Volan A and A-1100 Silane Finish Fabric

VI. **RECOMMENDED USES:**

Due to the results obtained in this investigation showing that the properties obtained with 181 A-1100 used as a reinforcement, are not equal to the ones obtained using Volan A finish fabric, it is recommended that where epoxy resins are to be used as a binder that Volan A finish fabric be used as a reinforcement.

VII. **SUPPLIERS AND TRADE NAMES:**

A. Vendors for 181 Volan A finish fabric and 181 A-1100 finish fabric include the following:

Coast Manufacturing Company
United Merchants
J. P. Stevens & Company, Inc.
Hess-Goldsmith and Company
Owens Corning Fiberglas Corporation

B. Availability

Standard rolls 125 yards long and 38 inches wide. Rolls with less and greater widths may be obtained for an additional cost.

C. Costs

Standard roll 125 yards long and 38 inches wide $1.13 per linear yard.

VIII. **REFERENCES:**

A. Lee and Neville, "Epoxy Resins".

B. Union Carbide, "A-1100 and A-172 Silane Glass Finishes".

AUTHOR: E. Lofton DATE: 9-11-61 PAGE 9.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Composite Materials **CODE:** 9-7-2

II. **MATERIAL NAME:** Reinforced Plastics for Radomes

III. **GENERAL DESCRIPTION:**

The data presented herein covers dielectric properties of some materials used for radome construction.

IV. **DEVELOPMENTAL BACKGROUND:**

This information was developed for use in computation of radome wall and sandwich thickness allowables and tolerances.

AUTHOR: J. Elton JE 15 August 1961

I. **CATEGORY:** Composite Material **CODE:** 9-7-2

II. **MATERIAL NAME:** Reinforced Plastics for Radomes

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Complete information not available due to lack of need for Boeing-Wichita's investigating this property.

I. CATEGORY: Composite Material CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. CATEGORY: Composite Material CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

C. Electrical Properties

The following table and graph presents data on a few thermosetting resins laminated with 181V (MIL-F-9084) glass fabric unless otherwise noted. Dielectric properties were determined per ARTC W-4.

To obtain the greatest specimen uniformity, laminates were prepared to 1/8" thick shims and resin content varied by varying the number of plies of fabric. The cured laminates were then bonded together with the same resin to form the complete specimen. This specimen was then machined to form the dielectric specimen. All polyester type resins were catalyzed with benzoyl peroxide. Epon 828 resin was catalyzed in the ratio of 28.5 parts by weight of Tonox to 100 parts resin.

I. **CATEGORY:** Composite Materials **CODE:** 9-7-2

II. **MATERIAL NAME:** Reinforced Plastics for Radomes

V. **PRINCIPAL PROPERTIES:**

SUMMARIZED DATA

A. **Electrical Properties**

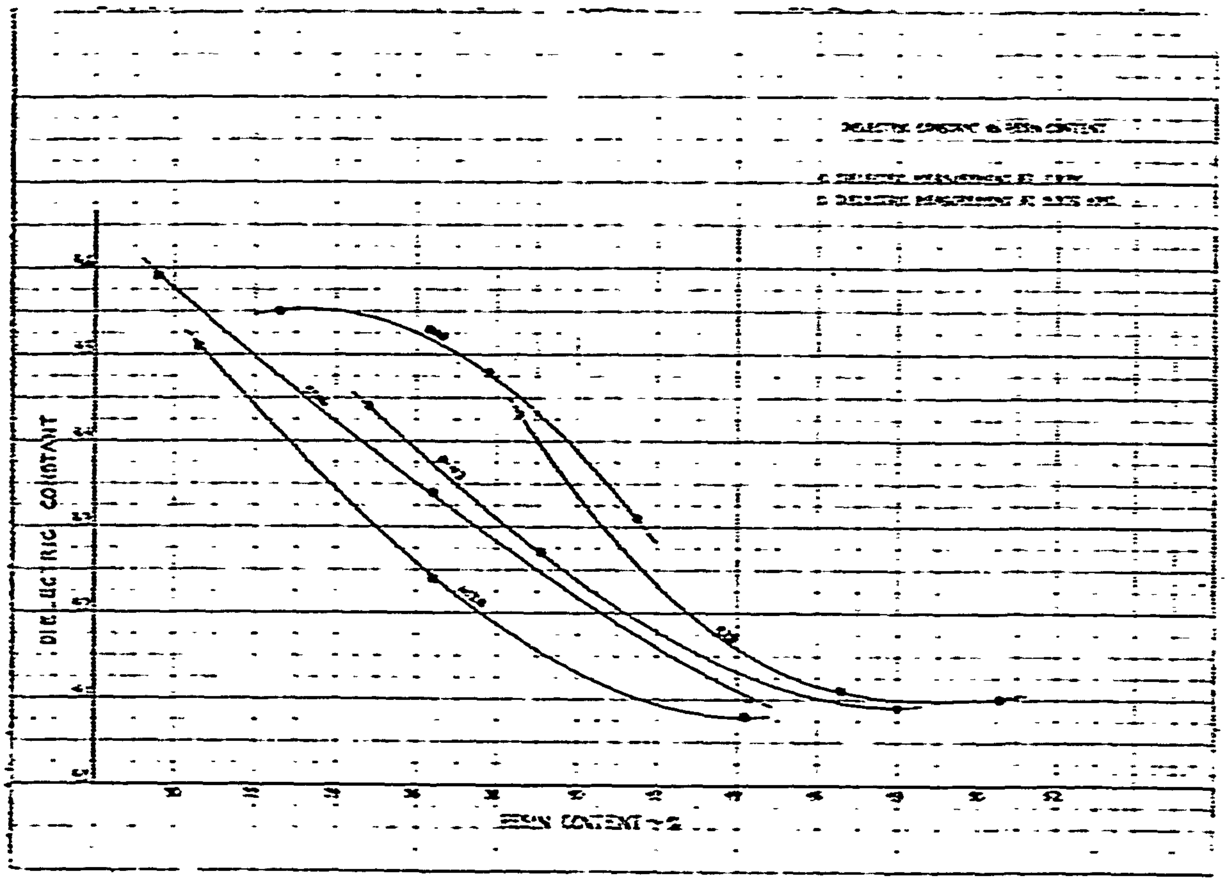
Laminate No.	No. of Plys 181 Volan	Type of Resin		Resin Content Coupon	Resin Content Dielectric Specimen	Specific Gravity	Dielectric Constant	Loss Tangent
		DIELECTRIC PROPERTIES MEASURED AT 11,000 MEGACYCLES						
1126	11	Epon	828	—	41.5	1.74	4.31	.021
1127	13	"	828	—	37.8	1.81	4.42	.017
1128	15	"	828	—	32.6	1.85	[illegible]	.018
1134	10	Laminac	4128	—	33.7	1.86	4.37	.011
1135	12	"	4128	32.9	34.1	1.88	4.46	.011
1136	14	"	4128	29.4	28.6	1.94	4.30	.011
1138	14	"	4128	—	32.3	1.90	4.43	.011
1139	10	Paraplex	P-43	—	48.0	1.74	4.09	.008
1142	12	"	P-43	—	39.1	1.82	4.27	.010
1145	14	"	P-43	—	34.8	1.85	4.44	.011
		DIELECTRIC PROPERTIES MEASURED AT 9,375 MEGACYCLES						
1169	12	Laminac	4128	35.9	36.4	1.83	4.21	.0066
1170	10	"	4128	44.0	44.2	1.72	4.02	.0084
1175	14	"	4128	30.2	30.6	1.92	4.51	.0078
1188	12	Selectron	5016	36.2	36.4	1.81	4.34	.0098
1196	14	"	5016	28.5	29.6	1.91	4.59	.0101
1197	10	"	5016	43.8	44.3	1.73	4.10	.0109
1198	10	Epon	828	46.3	46.6	—	4.11	.0188
1202	12	"	828	37.9	38.6	—	4.43	.0275
1206	9	"	828	50.7	50.6	1.63	4.30	.0186
FM-97	Scrimcloth	—	—	—	98.6	—	2.79	.0252
Epocast H991A	As Received No Glass						3.62	.0209
		CASTINGS AT 9,375 MEGACYCLES						
		Paraplex	P-43				2.91	.0069
		Laminac	4128				2.91	.0203
		Selectron	5016				2.90	.0145
		Epon	828				3.21	.0354

I. **CATEGORY:** Composite Materials **CODE:** 9-7-2

II. **MATERIAL NAME:** Reinforced Plastics for Radomes

V. **PRINCIPAL PROPERTIES:**

C. Electrical Properties



I. **CATEGORY:** Composite Materials **CODE:** 9-7-2

II. **MATERIAL NAME:** Reinforced Plastics for Radomes

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information not available due to lack of need for Boeing-Wichita's investigating this property.

I. CATEGORY: Composite Material CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

VI. RECOMMENDED USES:

Material properties govern usage for specific applications.

VII. SUPPLIERS AND TRADE NAMES:

1. Epon 828, Shell Chemical Corporation.
2. Laminac 4128, American Cyanamid Company.
3. Paraplex P-43, Rohm & Haas.
4. Selectron 5016, Pittsburgh Plate Glass.
5. FM-97, Bloomingdale Rubber Company.
6. Epocast H991A, Furane Plastics Company.
7. Tonox, Naugatuck Chemical Corporation.

VIII. REFERENCES:

1. Boeing-Wichita Materials and Process Unit Report No. AP-2-63, RB-47H Radome Material.

I. CATEGORY: Composite Materials CODE: 9-8-6

II. MATERIAL NAME: Decals

III. GENERAL DESCRIPTION:

A number of decals were investigated to determine their resistance to temperatures up to 800°F for periods of 30 minutes and 100 hours.

Three types of decals were included in this investigation:

1. Paint film decals.
2. Plastic film decals.
3. Metal-Cals (a trade name for decals produced on thin aluminum foil).

IV. DEVELOPMENTAL BACKGROUND:

A. Samples tested

1. Metal-Cal, silver letters on a red background, PS-3 adhesive. (This is a pressure sensitive, cellophane backed adhesive.)

2. Metal-Cal, silver letters on a black background, PS-3 adhesive. (This is a pressure sensitive, cellophane backed adhesive.)

3. Metal-Cal, PS-9 adhesive. (This adhesive is paper backed, and activated by heat or solvents.)

4. Metal-Cal, PS-10 adhesive. (This adhesive is paper backed, and activated by heat or solvents.)

5. Metal-Cal, Aluminum letters on a red background, PS-14 adhesive. (This is a pressure sensitive, paper backed adhesive.)

6. Metal-Cal, aluminum letters on a black background, PS-14 adhesive. (This is a pressure sensitive, paper backed adhesive.)

7. Paint film decal, white letters on a black background, water applied, slide-off.

8. Paint film decal, black letters on a gray background, face down, cement-applied.

9. Paint film decal, white letters on a brown background, water applied slide-off.

I. **CATEGORY:** Composite Materials CODE: 9-8-6

II. **MATERIAL NAME:** Decals

IV. **DEVELOPMENTAL BACKGROUND:** (Continued)

A. Samples tested (continued)

10. Paint film decal, white letters on a brown background, water applied, slide-off.

11. Paint film decal, white letters on a red background, water applied, slide-off.

12. Paint film decal, white letters on a black background, face down, cement-applied.

13. Paint film decal, black letters on a light gray background, face down, cement-applied.

14. Paint film decal, type "SHR" (sustained heat resistance), water applied, slide-off.

15. Paint film decal, type "HHR" (high heat resistance), water applied, slide-off.

16. Plastic film decal, Scotchcal SSB-133, upside-down construction, edges sealed with EC-866 Edge Sealer.

17. Plastic film decal, No. 3665 black Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.

18. Plastic film decal, No. 3650 white Scotchcal film, printed with No. 3905 (ANA No. 515) black Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.

19. Plastic film decal, No. 3651 red Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.

20. Plastic film decal, No. 3659 aluminum colored Scotchcal film, printed with No. 3905 (ANA No. 515) black Scotchcal Screen Process Paint. (No edge sealing or overcoating.)

I. CATEGORY: Composite Materials CODE: 9-8-6

II. MATERIAL NAME: Decals

IV. DEVELOPMENTAL BACKGROUND: (Continued)

A. Samples tested (continued)

21. Plastic film decal, No. 3667 Insignia Blue Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste and overcoated with No. 3920 Gloss Clear.

22. Plastic film decal, No. 659 aluminum colored Scotchcal film, overcoated with No. 3920 Gloss Clear.

23. Plastic film decal, No. 659 aluminum colored Scotchcal film, printed with No. 3905 (ANA No. 515) black Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.

24. Plastic film decal, No. 667 Insignia Blue Scotchcal film, overcoated with No. 3920 Gloss Clear.

25. Plastic film decal, No. 667 Insignia Blue Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste and overcoated with No. 3920 Gloss Clear.

NOTE: Plastic film decals 16-21 have a pressure sensitive adhesive; decals 22-25 have a solvent activated adhesive. No. 659 Scotchcal film is identical to No. 3659 except for the adhesive. No. 667 Scotchcal film is identical to No. 3667 except for the adhesive.

B. Procedure

Each decal was applied per the manufacturer's instructions to a clean metal panel (aluminum alloy QQ-A-287, 7075-T6 alclad, or stainless steel alloy QQ-S-766a, Type 321) aged a minimum of 48 hours at room temperature, and then placed in an oven and held at the designated temperature for 30 minutes or 100 hours. After cooling, the decals were examined.

I. **CATEGORY:** Composite Materials CODE: 9-8-6

II. **MATERIAL NAME:** Decals

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. **CATEGORY:** Composite Materials CODE: 9-8-6

II. **MATERIAL NAME:** Decals

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

The thermophysical properties of these decals are shown in Tables I and II.

I. **CATEGORY:** Composite Materials   **CODE:** 9-8-6

II. **MATERIAL NAME:** Decals

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical (continued)

Sample No.	Temperature, °F 200	300	350	400	450	500	600	700	800	900	1000
1	S	S	S	S	S	AP	AP,U	-	-	-	-
2	S	S	S	AL,S	AL,S	AP	AP,U	-	-	-	-
3	S	S	S	S	S	AL,S	AP,S	AP	AP,C,U		-
4	S	S	S	AL,S	AL,S	AL,S	AL,S	C,CE,S	AP,C	AP,C,U	-
5	-	-	-	-	-	AL,	AP,U	-	-	-	-
6	-	-	-	-	-	AL,S	AP,U	-	-	-	-
7	S	C,S	C,S	C,S	C,S	C,S	C	FA	AP,C,U	-	-
8	S	C,S	C,S	C,S	AP,C	-	-	-	-	-	-
9	S	C,S	C,S	C,S	C,S	C	AP,C	-	-	-	-
10	S	C,S	C,S	C,S	C,S	-	-	-	-	-	-
11	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	-	-	-	-
12	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	C	C,U	-	-
13	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	-	-	-	-
14	-	-	-	-	-	C,S	C,S	AP,C	AP,U	U	-
15	-	-	-	-	-	S	S	S	S	AP,S	AP,U
16	-	-	-	-	-	AP,E,U,Z	-	-	-	-	-
17	S	S	S	C,S	C,LG,S	AP,C,E,U	-	-	-	-	-
18	S	S	C,S	C,S	C,LG,S	AP,E,U	-	-	-	-	-
19	S	S	S	C,S	C,LG,S	AP,C,E,U	-	-	-	-	-
20	S	S	S	C,S	C,S	AP,C,E,U	-	-	-	-	-
21	S	S	S	C,S	C,S	AP,C,E,U	-	-	-	-	-
22	S	S	S	C,S	AP,U	-	-	-	-	-	-
23	S	S	S	C,S	AP,U	-	-	-	-	-	-
24	S	S	C,S	C,S	C,LG,S	-	-	-	-	-	-
25	S	S	C,S	C,S	C,LG,S	-	-	-	-	-	-

Effect of 30 Minute Exposure At Various Temperatures

TABLE I

I. **CATEGORY:** Composite Materials **CODE:** 9-8-6

II. **MATERIAL NAME:** Decals

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical (continued)

TEMPERATURE, °F

Sample No.	200	300	350	400	450	500	600	700	800
1	S	S	C,S	AL,C	AP,C,U	AP,C,U	-	-	-
2	S	S	AL	AL,C	AP,C,U	AP,C,U	-	-	-
3	S	S	AP	AP	AP,C,U	AP,C,U	-	-	-
4	S	S	AP	AP	AP,U	AP,C,U	-	-	-
5	S	S	S	AL	AL,C	AP,C,U	-	-	-
6	S	S	S	AL	AP,C,U	AP,C	AP,C,U	-	-
7	S	C,S	C,S	C,S	C	AP,C	U	-	-
9	S	C,S	C,S	AP,C	C	AP,C,U	-	-	-
11	S	C,S	C,S	C,S	C	AP,C	U	-	-
12	S	S	C,S	C,S	C	AP	U	-	-
13	S	C,S	C,S	C,S	C	C	U	-	-
14	S	S	S	S	C,S	S	AP,U	-	-
15	S	S	S	S	C,S	S	S	S	AP,U
16	S	C,S	C,E	AP,C,U	-	-	-	-	-
17	S	C,S	C,S	C,S	C,U	-	-	-	-
18	S	C,S	C,S	AP,C,U	-	-	-	-	-
19	S	C,S	C,U	-	-	-	-	-	-
20	S	C,S	C,S	C,S	C,S	AP,C,E,U	-	-	-
21	S	C,S	C,S	C,S	C,U	-	-	-	-

Effect of 100 Hour Exposure At Various Temperatures

TABLE II

I. CATEGORY: Composite Materials CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

C. Electrical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. **CATEGORY:** Composite Materials CODE: 9-8-6

II. **MATERIAL NAME:** Decals

V. **PRINCIPAL PROPERTIES:**

D. Chemical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. **CATEGORY:** Composite Materials **CODE:** 9-8-6

II. **MATERIAL NAME:** Decals

VI. **RECOMMENDED USES:**

It is recommended that the information in Tables I and II be used as a guide in predicting the probable temperature-time limitations of the decals tested. In case the operating conditions approach the limits indicated in these tables, further tests should be made.

VII. **SUPPLIERS, AVAILABILITY, AND COSTS:**

A. **Suppliers**

Decals 1 - 6 (Metal-Cals):	C & H Supply Company 1725 E. 2nd Street Wichita, Kansas or 421 E. Beach Avenue Inglewood 3, California or Seattle, Washington
Decals 7 - 9 (Paint film decals):	Warren Burdick Company 1815 North Broadway Wichita 4, Kansas
Decals 10 - 13 (paint film decals):	Woods-Beeton Decal Company 1710 Laura Avenue Wichita, Kansas
Decals 14, 15 (paint film decals):	The Meyercord Company 5323 West Lake Street Chicago 44, Illinois
Decals 16-25 (plastic film decals):	Minnesota Mining & Mfg. Company St. Paul 6, Minnesota
Edge Sealer No. EC-866:	Minnesota Mining & Mfg. Company St. Paul 6, Minnesota
No. 3920 Gloss Clear (overcoating material:	Minnesota Mining & Mfg. Company St. Paul 6, Minnesota

I. CATEGORY: Composite Materials CODE: 9-8-6

II. MATERIAL NAME: Decals

VII. SUPPLIERS, AVAILABILITY, AND COSTS: (Continued)

A. Suppliers (continued)

Scotchcal Screen Process Pastes, No. 3905 (black) and No. 3903 (white):	Minnesota Mining & Mfg. Company St. Paul 6, Minnesota
Adhesives PS-3, PS-9, PS-10, and PS-14:	Minnesota Mining & Mfg. Company St. Paul 6, Minnesota

B. Availability

All materials listed are believed to be currently available from the manufacturers.

C. Costs

The cost of the decals varies with a number of factors, such as size, printing, number ordered etc., so that no estimate of cost can be given.

VIII. REFERENCE:

1. Boeing Company Materials and Process Unit Document D3-1598, "Temperature Limitations of Marking Materials (Phases I, II, III, and IV)".

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous and General CODE: 0-1-4

II. **MATERIAL NAME:** Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

III. **GENERAL DESCRIPTION:**

The objective of this program was to develop biphenyl compounds carrying functional groups that would permit polymerization to be accomplished. The biphenyl nucleus is known to impart thermal stability to compounds that contain it.

IV. **DEVELOPMENTAL BACKGROUND:**

After three unsuccessful attempts to prepare 2,2', 3,3',4,4'-tetrahydroxybiphenyl by the C. Harries method described in Reference (2), a modification of the method as proposed in Reference (3) was successfully carried out. An aqueous solution of pyrogallol was mixed with a barium hydroxide solution, agitated, air excluded and finally acidified with HCl. The precipitated product was washed with water and recrystallized from water containing acetic acid.

AUTHOR: Chris Henriksen 17 August 1961

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

A. Mechanical

As prepared, this material is a white, finely divided powder.

AUTHOR: Chris Henriksen CH. 17 August 1961

MATERIALS & PROCESS UNIT

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The compound darkens at approximately 280°C and melts at 310°-320°C. with decomposition.

I. CATEGORY: Miscellaneous and General CODE: G-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita investigating this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

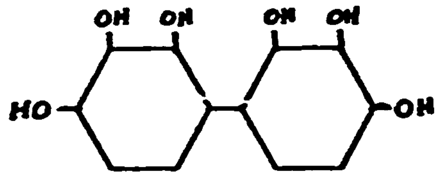
I. **CATEGORY:** Miscellaneous and General **CODE:** 0-1-4

II. **MATERIAL NAME:** Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

V. **PRINCIPAL PROPERTIES:**

D. Chemical

The formula for 2,2',3,3',4,4' hexahydroxybiphenyl is:



The hydroxyl groups permit various degrees of modification to form esters, ethers and other compounds of interest. The epoxy substituted material is expected to have desirable characteristics. After curing with a hardening agent such as an amine or an anhydride, the resulting polymer should be highly cross-linked; this fact, together with the biphenyl back-bone structure should provide good thermal and chemical stability.

AUTHOR: Chris Henriksen CH. 17 August 1961

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl

VI. RECOMMENDED USES:

Preparation of polymers. For example, the hexaglycidyl ether can be prepared and hardened with the usual epoxy hardeners. New resins of this type represent an unexplored field. The biphenyl backbone structure is expected to impart both thermal and chemical stability to such resins.

VII SUPPLIERS:

None.

VIII. REFERENCES:

(1) D3-2867, "Molecular Engineering", C. A. Henriksen, 9 February 1960.

(2) Berichte der Deutschen Gesellschafft. Ber. 35 2954-9 (1902).

(3) Harries Di-Pyrogallol. Proc. Roy Soc. (London) A143, 207-8 (1933-4).

AUTHOR: Chris Henriksen 17 August 1961 PAGE 6

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

III. GENERAL DESCRIPTION:

The object of this program was to establish autoignition temperatures (AIT) of JP-4 fuel over a pressure range of 500 mm Hg to 2000 psi.

IV. DEVELOPMENTAL BACKGROUND:

This program was initiated as a result of considerable concern about the maximum operating temperatures of "Black Boxes" and air compressors on B-52 aircraft that might contact combustible concentrations of fuel vapors. A literature search for AIT information at various pressures indicated a need for additional experimental data.

Although standard definitions and methods of determination have been established for many of the physical and chemical properties of JP-4 fuel, there has been no general agreement on the definition or determination of ignition temperatures, consequently, determinations of this property by different investigators have varied widely both in numerical value and significance, with much resulting confusion and difficulty in the interpretation and practical application of the information.

It appears that, although the ignition characteristic of a material is doubtless a function of some actual property of the material, the measurement of that property by any means available is greatly affected by the ambient conditions, therefore, any practical definition of AIT which might be adopted must continue to be based on a careful definition and standardization of the test apparatus and procedure.

The apparatus and test procedure used for AIT determinations at simulated altitudes were those described in ASTM D 286-58T with modification to allow determinations at reduced pressures.

The value at 2200 psi (1.14×10^5 mm Hg) was determined using a high pressure stainless steel bomb (150 cc volume) with instrumentation to permit the recording of temperature and pressure within the bomb. The method for determining AIT with this bomb consisted of placing a specified amount of fuel in the bomb, pressurizing the bomb to the desired pressure, and heating the bomb until an ignition was obtained. The temperature at which the ignition occurred was the AIT of the fuel at the pressure recorded just prior to ignition. A pressure rise in excess of 8 times the initial pressure was estimated to have occurred upon ignition.

AUTHOR: J. R. Gibson DATE: 9-11-61

MATERIALS & PROCESS UNIT

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Not applicable

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The autoignition temperatures established for the pressure range investigated are presented in Figure I. Data from other investigators are presented for comparison.

AUTHOR: J. R. Gibson DATE: 9-11-61 PAGE 3

MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical (cont'd)

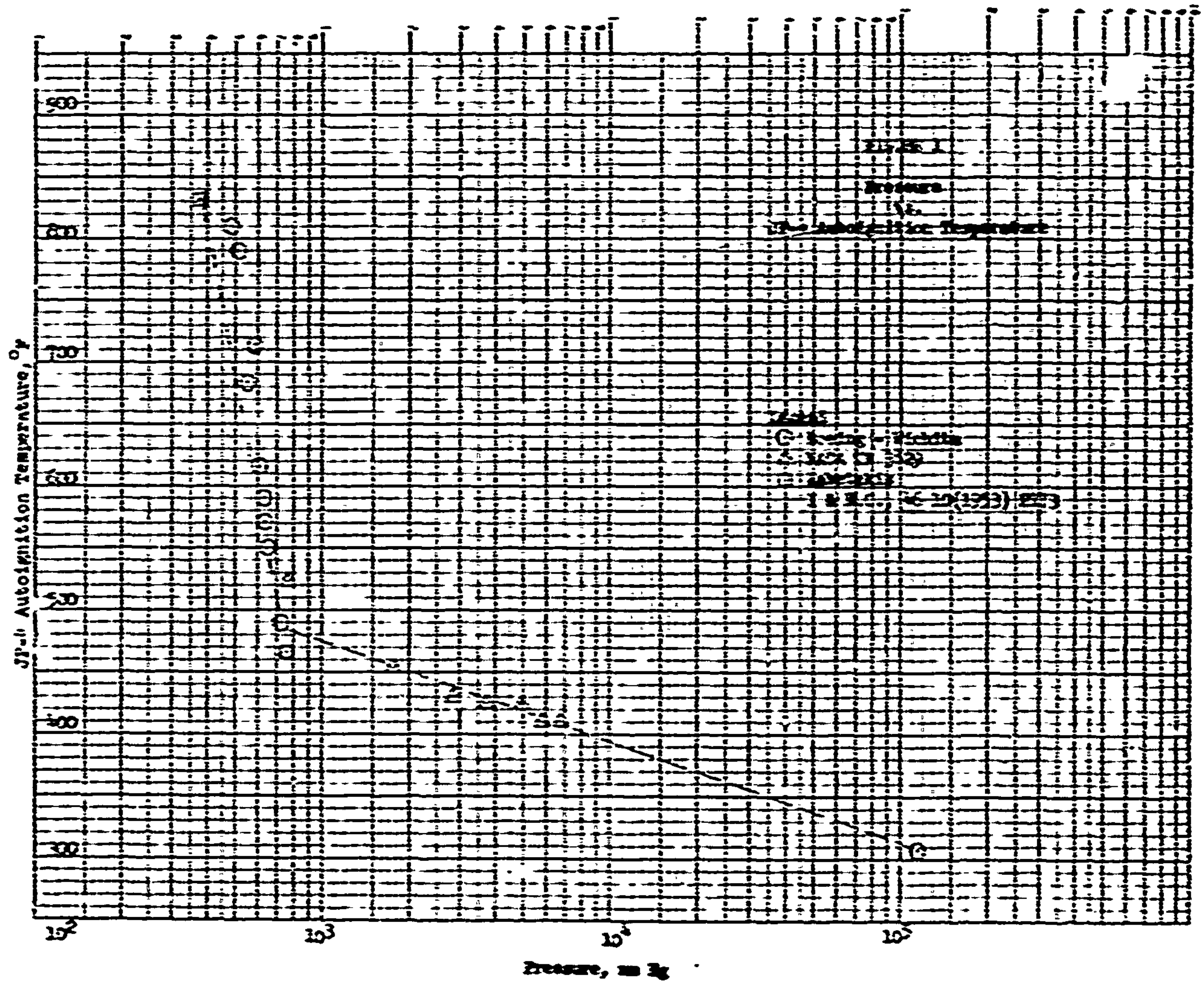


FIGURE I

AUTHOR: J. R. Gibson DATE: 9-11-61 PAGE 1

MATERIALS & PROCESS UNIT

326

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

V. **PRINCIPAL PROPERTIES:**

C. **Electrical**

Information not available due to lack of need for Boeing - Wichita's investigating this property.

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

V. **PRINCIPAL PROPERTIES:**

D. Chemical

The fuel used during this investigation met MIL-J-5624E specifications.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous and General **CODE:** 0-5-0

II. **MATERIAL NAME:** JP-4 Fuel (MIL-J-5624E)

VI. **RECOMMENDED USES:**

It is recommended that the autoignition data presented herein be considered during the design of "Black Boxes", air compressors, etc., when the possibility of fuel contact exists.

VII **SUPPLIERS AND TRADE NAMES:**

Major petroleum companies

VIII. **REFERENCES:**

1. ASTM Standards 1958, Part 7, Test Method D286-58T

2. Boeing - Wichita Materials and Process Unit Job No. SM-2-58

3. O'Neal, Cleveland Jr., Effect of Pressure on the Spontaneous Ignition Temperature of Liquid Fuels. NACA TN 3829

4. Zabetakis, M. G., Furno, A. L., and Jones, G. W.: Minimum Spontaneous Ignition Temperatures of Combustibles in Air. Ind. and Engr. Chem., Vol. 46, No. 10, Oct. 1954 pp 2173-2178

AUTHOR: J. R. Gibson DATE: [illegible]

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous General   **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, and 321-A Stainless Steel

III. **GENERAL DESCRIPTION:**

The objective of the program was to establish maximum angular shearturning capabilities for standard airframe materials, in varying thicknesses.

IV. **DEVELOPMENTAL BACKGROUND:**

This program deals primarily with the extension and determination of shear-turning capabilities and its limits. Essentially, this report discusses and fixes the angles to which a given material may be shearturned without failure.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:**

A. Mechanical

Maximum angular limits for shearturn quality materials are:

321-A	15°
7075-0	16-1/2°
2024-0	16-1/2°

See Photograph BWA-23473

The limits established during testing are shown in Tables I, II and III, and seen in the plotted graphs of Figures 1, 2, and 3. The values shown in these tables supersede the above maximum angular limits at any thickness than .090" or greater than .190".

The above angles are defined as 1/2 the included angle of the part.

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous General   **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. **Mechanical** (continued)

BWA-23473

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

	Material		Machine Settings				Test Results		Computations		Comments
Sample Number	Type	Original Thickness	Roller Nose Radius	Feed Rate	RPM	Template Nose Setting	Angle at Break	Thickness at Break	Sine	Angle	
1	2024-0	.262	3/16	2½	320	T.	-18°	.080	.301	17½°	
2	"	"	3/16	2½	320	T.	-18°	.080	.301	17½°	
3	"	"	3/16	2½	650	T.	-17°	.071	.271	15¾°	
4	"	"	3/16	2½	350	T.	-18°	.075	.278	16°	
5	"	"	3/16	2½	650	T.	-17°	.069	.263	15°	
6	"	"	3/16	2½	1000	T.	-17°	.069	.263	15°	
7	2024-0	.186	3/16	2½	350	T.	15°	.041	.220	13°	
8	"	"	3/16	2½	550	T.	15°	.042	.226	13°	
9	"	.181	3/16	2½	650	T.	-15°	.041	.226	15°	
10	"	.187	3/16	2½	1000	T.	15°	.041	.219	13°	
11	7075-0	.187	3/16	2½	350	T.	-16°	.048	.230	15°	
12	"	.188	3/16	2½	350	T.	16°	.043	.228	13°	
13	"	"	3/16	2½	650	T.	16°	.041	.218	15°	
14	"	"	3/16	2½	1500	T.	-16°	.040	.212	12°	
15	321-A	.195	3/16	2½	350	.125	18°	.037	.190	11°	Tight
16	"	.156	3/16	2½	350	.150	-16°	.031	.160	9°	Tight
17	"	"	3/16	2½	250	.175	-15°	.033	.170	10°	Tight
18	"	.195	3/16	2½	250	.180	-15°	.034	.174	10°	Tight
19	2024-0	.125	3/16	2½	350	T.	16°	.026	.208	12°	
20	"	"	3/16	2½	350	T.	-15°	.026	.208	12°	
21	"	"	3/16	2½	350	T.	-15°	.026	.208	12°	
22	"	"	3/16	2½	350	T.	-15°	.029	.222	13°	
23	"	"	3/16	2½	650	T.	-15°	.028	.226	13°	
24	"	"	3/16	2½	1000	T.	-16°	.027	.216	12°	

TABLE I

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

Sample Number	Material		Machine Settings				Test Results		Computations		Comments	
	Type	Original Thickness	Roller Nose Radius	Feed Rate	RPM	Template Nose Setting	Angle at Break	Thickness at Break	Sine	Angle		
25	7075-0	.127	3/16	2½	350	T.	15°	.033	.260	15°		
26	"	"	3/16	2½	350	T.	16°	.035	.276	16°		
27	"	"	3/16	2½	350	T.	15°	.031	.245	14°		
28	"	"	3/16	2½	350	T.	-16°	.034	.268	15°		
29	"	"	3/16	2½	650	T.	-15°	.029	.228	13°		
30	"	"	3/16	2½	1000	T.	-15°	.030	.236	14°		
31	321-A	.121	3/16	2½	350	.110	16°	.042	.347	20°	Loose	
32	"	"	3/16	2½	350	.090	16°	.035	.272	16°		
33	"	"	3/16	2½	350	.090	-14°	.033	.272	16°		
34	"	"	3/16	2½	650	.090	-14°	.026	.215	12°		
35	"	"	3/16	2½	1000	.090	-14°	.024	.198	11°		
36	2024-0	.091	1/8	2½	350	T.	+22°	.038	.418	25°	Loose Against Template	
37	"	"	1/8	2½	350	T.	+17°	.025	.275	16°	"	"
38	"	"	1/8	2½	350	.086	16½°	.022	.242	14°		
39	"	"	1/8	2½	350	.086	16°	.024	.266	15°		
40	"	"	1/8	2½	350	.086	16°	.022	.242	14°		
41	"	"	1/8	2½	650	.086	+16°	.022	.242	14°		
42	"	"	1/8	2½	1000	.086	+16°	.022	.242	14°		
43	7075-0	.040	1/8	2½	350	T.	+15°	.022	.245	14°		
44	"	"	1/8	2½	350	T.	16°	.023	.256	15°		
45	"	"	1/8	2½	350	T.	-15°	.021	.234	14°		
46	"	"	1/8	2½	350	T.	15°	.021	.234	14°		
47	"	"	1/8	2½	650	T.	15°	.021	.234	14°		
48	"	"	1/8	2½	350	T.	15°	—	—	—		

TABLE II

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. **Mechanical** (continued)

	Material		Machine Settings				Test Results		Computations		Comments
Sample Number	Type	Gauge Thickness	Roller Nose Radius	Feed Rate	RPH	Template Nose Setting	Angle at Break	Thickness at Break	Sine	Angle	
49	321-A	.090	1/8	2 1/2	350	.070	-15°	.022	.244	14°	
50	"	"	1/8	2 1/2	350	.070	15°	.022	.244	14°	
51	"	"	1/8	2 1/2	350	.070	15°	.020	.222	13°	
52	6061-T	.061	1/8	2 1/2	350	T.	-17°	.016	.262	15°	
53	"	"	1/8	2 1/2	350	T.	14°	.015	.246	14°	
54	"	"	1/8	2 1/2	350	T.	-15°	.015	.246	14°	
55	"	"	1/8	2 1/2	350	T.	-15°	.015	.246	14°	
56	7075-0	.040	1/8	2 1/2	350	.050	—	—	—	—	loose
57	"	"	1/8	2 1/2	550	.045	—	—	—	—	"
58	"	"	1/8	2 1/2	350	.040	16°	.021	.275	16°	
59	"	"	1/8	2 1/2	350	.040	-17°	.019	.250	15°	
60	2024-0	.018	1/8	2 1/2	550	.020	—	—	—	—	
61	"	"	1/8	2 1/2	350	.017	-22°	.008	.445	26°	
62	"	"	1/8	2 1/2	350	.015	22°	.007	.390	23°	
63	"	"	1/8	2 1/2	350	.015	20°	.007	.390	23°	
64	"	"	1/8	2 1/2	350	.015	18°	.006	.334	20°	
65	A-286	.022	1/8	2 1/2	350	.019	22°	.010	.455	27°	
66	"	"	1/8	2 1/2	350	.015	20°	.008	.364	21°	
67	"	"	1/8	2 1/2	350	.012	20°	.008	.364	21°	

TABLE III

AUTHOR: F. W. Stratton DATE: 9-13-61 PAGE 6.

I. **CATEGORY:** Miscellaneous General   **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

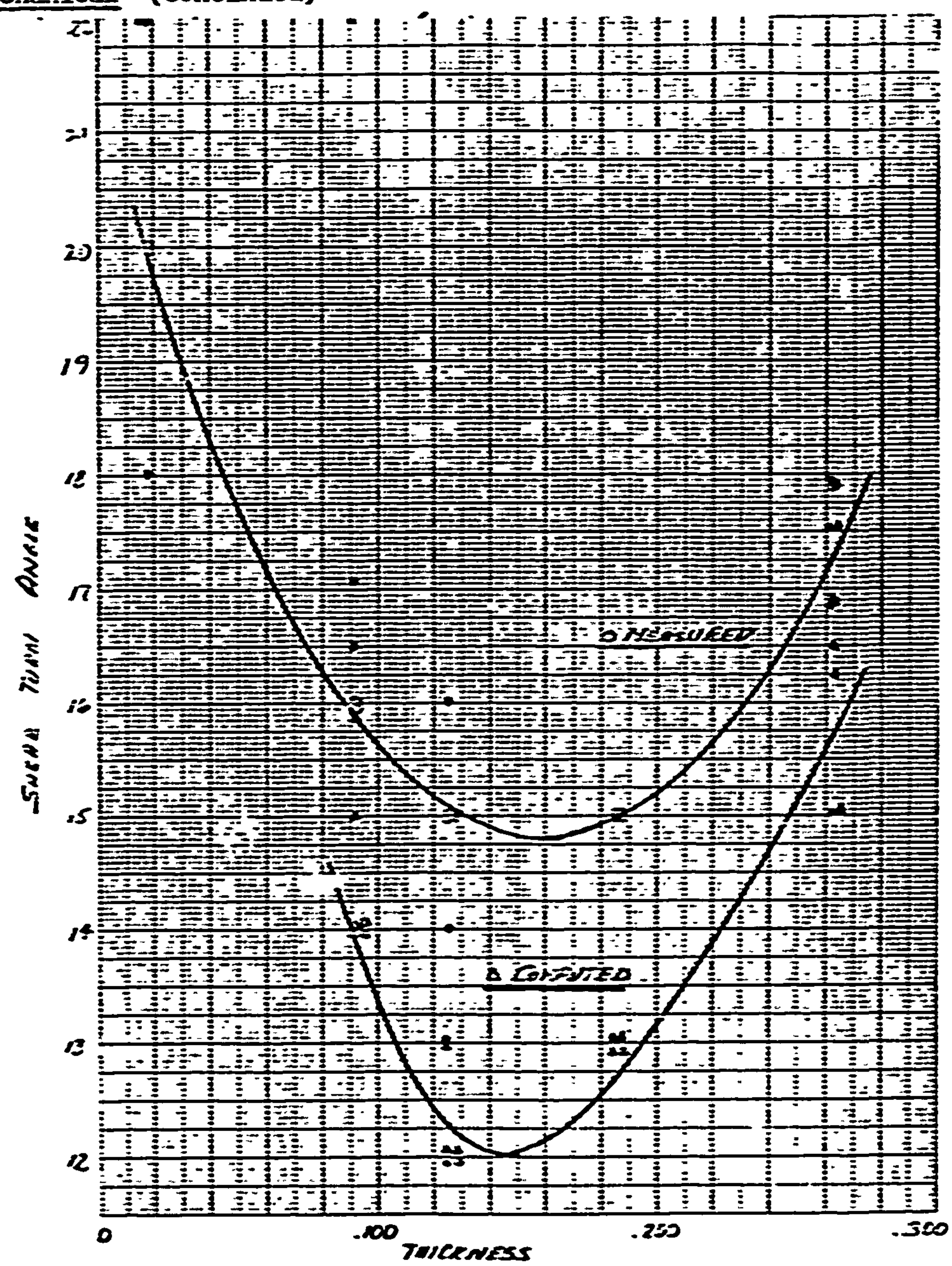


FIGURE 1

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Miscellaneous General CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

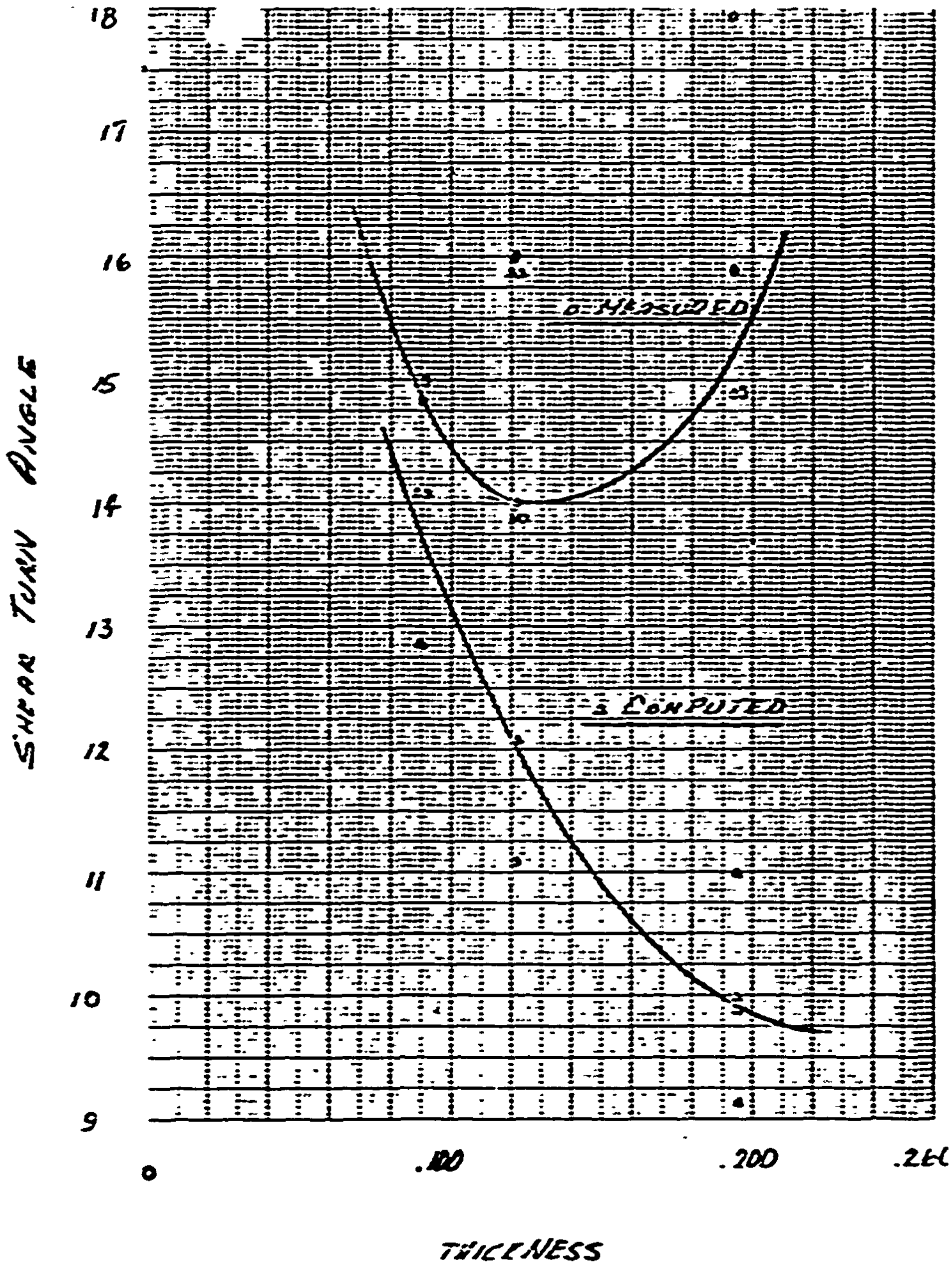


FIGURE 2

AUTHOR: F. W. Stratton DATE: 9-18-61 PAGE 8.

MATERIALS & PROCESS UNIT

337

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:** (Continued)

A. Mechanical (continued)

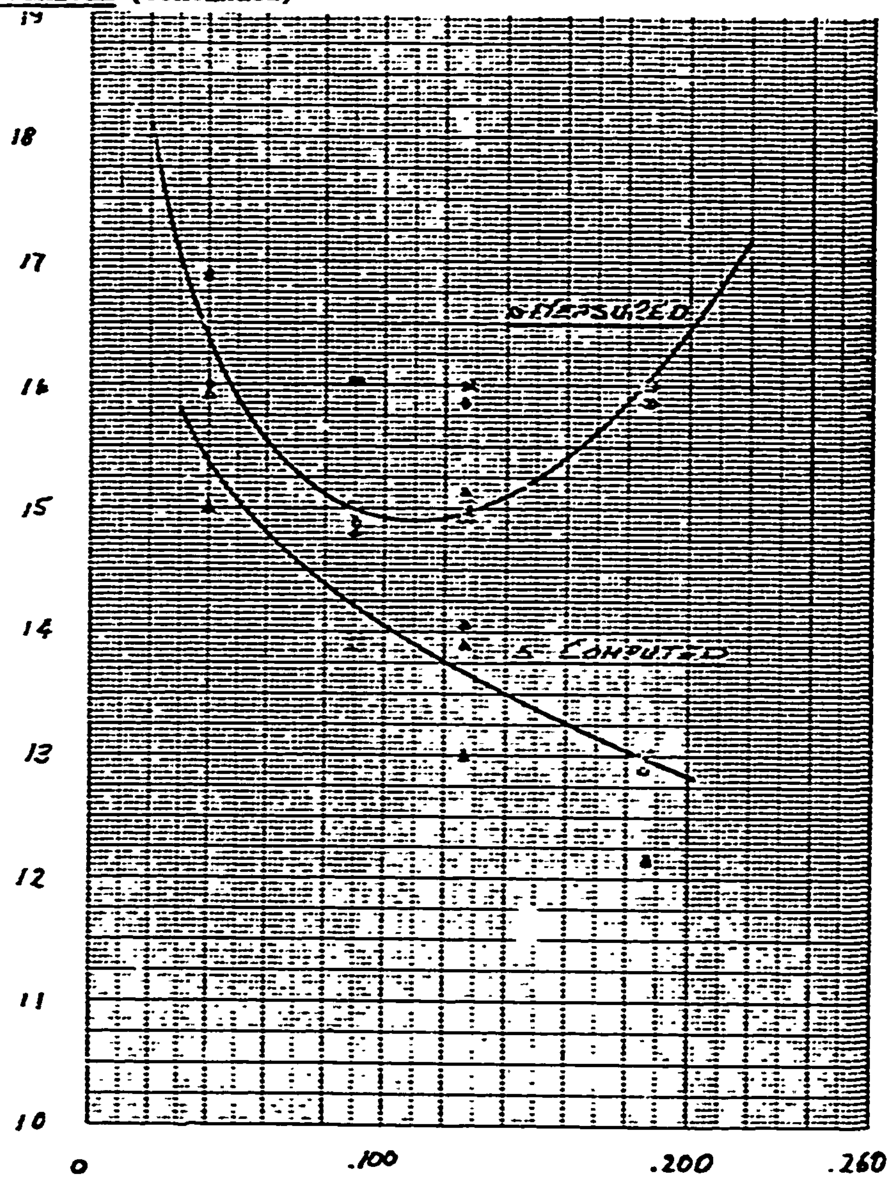


FIGURE 3

AUTHOR: F. W. Stratton DATE: 9-18-61 PAGE 9.

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:**

B. Thermophysical

This property has not been determined by Boeing-Wichita since such information was not needed under the scope of this program.

I. CATEGORY: Miscellaneous General CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES:

C. Electrical

This property has not been determined by Boeing-Wichita since such information was not needed under the scope of this program.

I. **CATEGORY:** Miscellaneous General **CODE:** 0-7-1

II. **MATERIAL NAME:** Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. **PRINCIPAL PROPERTIES:**

D. Chemical

This property has not been determined by Boeing-Wichita since such information was not needed under the scope of this program.

I. CATEGORY: Miscellaneous General CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with thin end usage in mind and the test procedure derived to make possible the determination of the property of new materials, should such materials call for the process of shearturning.

VII. SUPPLIERS AND TRADE NAMES:

Available from all standard Metal suppliers.

VIII. REFERENCES:

A. Boeing-Wichita Manufacturing Research Report 64.5, "Angular Shear Displacement Limits for Shearturned Metals".